

ASTRONOMY[®]

SEEING MARS AT ITS BEST

Test Report: Meade's LX200 Telescope

Exploding Star Reveals All

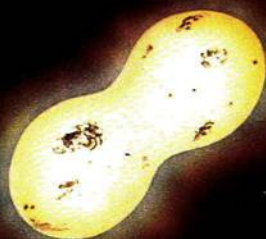
July 1993 U.S. \$2.95

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Dance of the **DOUBLE SUN**



- **Computing Jupiter's Great Red Spot**
- **How to Get Razor-Sharp Photos**

MEADE®

Optics: research-grade SC optics, the finest ever offered the advanced amateur. Specify either f/6.3 or f/10.

Supplied complete per catalog specifications*:

8" LX200 Schmidt-Cassegrain	\$2295.
Equatorial Wedge 8"	110.
10" LX200 Schmidt-Cassegrain	2595.
Superwedge 10"	395.

8" LX100 Schmidt-Cassegrain with wedge	1995.
10" LX100 with Superwedge	2695.

Packing and shipping in the 48 states: 8"—\$105; 10"—\$145

■ All prices shown are suggested USA mail-order retail prices, exclusive of sales taxes or credit card charges, if applicable.

■ For dealer or catalog information see the Meade ED Apochromatic Refractor ad in this issue.

Multi-Coated Optics (not available on any competing Schmidt-Cassegrains) are standard equipment.

Each LX200 includes 8 x 50mm viewfinder, diagonal prism, and Series 4000 SP26mm eyepiece.

Meade 10" LX200

Power Consumption: Operate your LX200 all night from an auto cigarette lighter plug with **zero** risk of battery drain, or use the standard equipment 115v AC adapter. Competing computer telescopes use up to 16 times more electric current and **require** you to carry around a 44-lb. storage battery (and purchase a battery recharger) just to operate the telescope!

Meade Smart Drive™ (not available on competing computer telescopes) yields an observatory standard 5 arc. sec or less of periodic tracking errors.

Altazimuth Operation: Just set up your LX200 directly on the tripod (without a wedge!) and observe. The telescope's computer tracks on **both** axes to keep objects precisely centered.

Power Panel connectors for RS-232, CCD cameras, electric focuser, illuminated reticle eyepiece, and more.

Digital and Information Readouts conveniently read directly from the hand-held keypad controller.

Optional 8" wedge or 10" superwedge, shown, is required only for long-exposure astrophotography.

Meade 8" LX200

The largest, most rigid fork mountings ever manufactured for commercial Schmidt-Cassegrains.

Enter any of 747 library objects into the keypad, press GO TO and the telescope slews to the object at 8°/sec. (8000-object library available optionally at \$99.)

Pushbutton electric slew: press RA or Dec slew and the telescope moves at 8°/sec on both axes.

4-speed operation on both axes: 2x, 32x, 2°/sec., 8°/sec.

Enter into the keypad the RA and Dec of any object, press GO TO, and the telescope automatically slews to the object at 8°/sec.

LX200 SCHMIDT-CASSEGRAINS

The largest-selling serious telescopes in the world.

Now you can buy the most advanced 8" and 10" Schmidt-Cassegrains ever produced, at a price directly competitive with other SCT's offering only a fraction of the features!

Meade LX200 SCT's offer a revolutionary departure from any other SCT's ever made available. Consider the **standard specifications** of these telescopes:

New Heavy-Duty Fork Mounts—The largest, most rigid in the industry. Meade 8" and 10" LX200 fork mounts yield the lowest damping times of any SC fork mounts available. Large 4"-diameter polar ball bearings complemented by DC-servo-motor-driven worm gears on **both** telescope axes permit observatory-level precision in tracking, guiding, and slewing.

100% Computer-Controlled Operation—All-new Meade LX200 microprocessor-controlled drive systems offer an incredible array of features:

■ **Four-speed operation on both telescope axes** simultaneously, including (a) photo-guiding (at 2x sidereal rate); (b) image centering and microslowing in the main telescope (at 32x sidereal rate); (c) image centering in the viewfinder (at 2° per sec.); or fast-slew of the main telescope across the skies (at 8° per sec.).

■ **Pushbutton Electric Slew**—Press RA or Dec slew, east or west, north or south, and the telescope moves at 8° per sec. on both axes. As you near a desired object, flip to 2° per sec. slew, to center the object in the field. The observer need never touch the telescope in moving from one object to another. (Of course, if you wish, the telescope may be moved manually as well.)



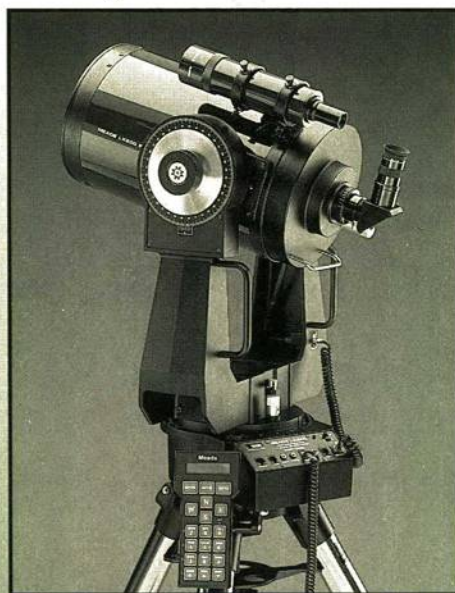
■ **Digital Readouts** on both axes, read from the handheld Electronic Command Center (ECC).

■ **GO TO Capability**—Enter the RA and Dec of an object into the keypad of the ECC, press GO TO, and the telescope automatically slews to the object at 8° per sec., centering it in the field.

■ **747-Object Built-in Library**—Enter any of the 110 Messier objects, 278 of the finest NGC objects, 351 stars (doubles, variables, polar reference stars), or one of the 8 planets, from Mercury to Pluto, press GO TO, and the telescope slews at 8° per sec. to the object with uncanny precision. For \$99* add the 8000-object Meade CNGC library, a 30-second plug-in.

■ **Permanently programmable (PPEC) Smart Drive™**, capable of reducing periodic drive errors to 5 arc. sec. or less.

Legendary Meade Super Multi-Coated f/6.3 or f/10 Schmidt-Cassegrain Optics—Now you can choose either wide-field f/6.3 or classical f/10 Meade US-made SC optics at the same price. Either way, you'll be buying the finest Schmidt-Cassegrain optical system available, a system that yields razor-sharp stellar images and high-resolution observing of the Moon, planets, and deep-space, from the World's leading manufacturer. Meade exclusive Super Multi-Coatings on both sides of the correcting plate assure maximum light transmission and contrast.



Altazimuth Mode Operation—For all visual observing applications, and for lunar and planetary photography, Meade LX200's may be set up in the altazimuth mode, without any equatorial wedge—just attach the telescope's drive base directly to the tripod, use the fast 1-star alignment procedure, and the telescope's computer actuates 2-axis tracking that keeps objects precisely centered in the field, even at high powers, during the entire observing session. For long exposure photography (longer than about 5 minutes) altazimuth-induced field rotation requires an equatorial wedge, which may be purchased separately.

Fast Polar Alignment—Center two reference stars in the telescopic field and the telescope's computer tells you exactly what telescope controls to actuate for precise polar alignment in the equatorial mode in less than a minute.

The widest array of keypad and power-panel control functions—In addition to the microprocessor-controlled operations listed above, the handheld ECC and the telescope's power panel

permit: readout of sidereal or local time; actuation of the optional electric focuser; crossline brightness control of an illuminated reticle eyepiece; direct plug-in of popular CCD autoguider/imagers; and more than 14 other telescope functions.

MEADE LX100 SCHMIDT-CASSEGRAINS

Observers not requiring the sophistication of the LX200 electronics may wish to consider an 8" or 10" LX100 model SCT instead. Meade LX100's include the exact same heavy-duty fork mounts of their LX200 counterparts, but with a microfine declination tangent arm control in place of the LX200's motorized worm gear, and with a 2-speed drive in place of the LX200's 4-speed drive; optical tubes and coatings are identical. Standard LX100 features include:

■ **Handheld Electronic Command Center**—With 2-speed operation, 2x for photo-guiding and 32x for image centering and microslowing in the main telescope. (With the optional DC-servo declination motor installed, these speeds are operational on both telescope axes.)

■ **Permanently programmable (PPEC) Smart Drive**, as described above.

Complete LX100 and LX200 Telescopes

Specifications: 8" and 10" LX200's—Each complete telescope includes: 8" or 10" SC optical tube assembly (specify f/6.3 or f/10) with super multi-coatings; heavy-duty fork mount, with 4" polar ball bearing, dual-axis 5.75" worm-gears, and multi-function power panel display on the drive base; manual slow-motion controls on both axes; handheld keypad Electronic Command Center, with digital readout display, PPEC Smart Drive, four-speed drive control on both axes, GO TO controller, and 747-object software library; 25 ft. power cords for telescope operation from either 12 v. DC auto cigarette lighter plug or 115v.AC; 8 x 50mm viewfinder with crosshairs; diagonal prism (1.25"); Series 4000 Super Plössl 26mm eyepiece; variable-height field tripod; new deluxe die-cut-foam-fitted carrying case; complete operating instructions.

Specifications: 8" and 10" LX100's—Each complete telescope includes 8" or 10" SC optical tube assembly (specify f/6.3 or f/10) with super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, 5.75" RA worm gear, and multi-function power panel display on the drive base; manual slow-motion controls on both axes; handheld pushbutton Electronic Command Center with PPEC Smart Drive and 2-speed drive control; 25 ft. power cords for telescope operation from either 12v. DC auto cigarette lighter plug or from 115v. AC; viewfinder: 6 x 30mm (8") or 8 x 50mm (10"); diagonal prism (1.25"); Series 4000 Plössl 26mm eyepiece; variable-height field tripod; equatorial wedge (8") or Superwedge (10"); new deluxe die-cut-foam-fitted carrying case; complete operating instructions.

Meade Instruments has moved!

Effective May 1, 1993, Meade Instruments has moved to new office and manufacturing facilities in Irvine, Calif., about 10 miles from our previous location. The new 56,400 sq. ft. Meade facility is the world's largest, most advanced commercial telescope manufacturing operation. Please note new address, telephone, and FAX numbers below.



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ON THE COVER: No, this isn't the Sun seen in double vision. This is ER Vulpeculae, an exotic binary system whose stars could each pass for the Sun except they spin 40 times faster. The rapid spin creates strong magnetic fields and huge starspots. To discover the intriguing fate of these stars, turn to page 26. Illustration by Michael Carroll.

SUPER-SHARP IMAGES of deep-sky objects, like that of the Omega Nebula (M17) in Sagittarius shown here, can be yours if you know how to focus your camera precisely. See page 58 to learn the tricks of the trade.



20th
ANNIVERSARY YEAR

ASTRONOMY

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SEEING MARTIAN VOLCANOES

Did you get a look at Mars last winter and spring? I sure hope you did. It was *beautiful*. The soft-edged ochre disk swam gently in the eyepiece, and the dark markings slowly drifted across the planet's face as the hours rolled by. This year's wasn't a close opposition for Mars, but it was a very pretty one.

One of the many benefits of backyard astronomy is that telescope owners can "have" Mars whenever it's visible. For the general public, however, the planet pops into view only when a spacecraft visits it. Indeed Mars will be in the news again pretty soon: The Mars Observer space probe arrives next month and will start taking pictures in December, after some orbital maneuvering.

Amateur observers and spacecraft each have a particular vision of Mars. But these visions are so different that it's almost as if each is viewing a different planet. The gigantic disparity in resolution — in surface details you can see — makes an unbridgeable gap that forever separates the backyard Mars from that which a spacecraft can show us.

Or does it? Looking at the images that accompany the story by Don Parker and Richard Berry, what caught my eye most was the sequence you'll see on page 74. These images are remarkable, although the first simply shows Mars about the way you see it in a telescope: soft in color, with faint dark markings.

But look what happens as you increase the contrast and filter the image to bring out details. Step by step you can see a new view of Mars slowly emerge. The last image in the sequence is exactly the same one as the first, but what a difference processing makes! Do you see on the left the four bluish specks, three in a line and one off to the side? These aren't defects in the photo. They're ice clouds floating over the giant volcanoes of Tharsis. There they are Arsia Mons, Pavonis Mons, Ascraeus Mons — and the big one, Olympus Mons.

It's still true that you can't explore the landslides of Valles Marineris with an 8-inch telescope. These features and many more will remain securely in the domain of space probes, probably forever. But as Parker and Berry's story makes clear, there's a great deal you *can* see on Mars — and the other planets. Likely much more than you think.

By the way, I hope you can get to Universe '93 this summer. Held in San Diego on July 10 and 11, it will be the grandest, most exciting telescope fair and amateur astronomy convention ever. (See the notice on page 98.) Jointly sponsored by the Astronomical Society of the Pacific and *ASTRONOMY*, Universe '93 will be jam-packed with great things to see and do. *ASTRONOMY*'s editors and art director will be there and we're looking forward to seeing you.

Sincerely,



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Shotgun Diplomacy

Peter Leschak's Viewpoints article "Insecurity Light" (April 1993) was superb. Like Mr. Leschak, I too have been tempted to "blow away" a streetlight to gain a dark sky. At the time I was living in suburban Washington state. The offending light had been installed by a well-meaning neighbor concerned about home security.

Soon after it appeared, I began to plot the demise of the mercury vapor demon that plagued me. I formulated a plan. Late at night, under the cover of artificial light, I would extinguish the vile mercury plasma by passing a .22-caliber bullet through its heart. Although I never carried out my plan, for a time it was a wonderful fantasy.

As a former police officer I know that most attempts at home security are ill-conceived and poorly executed. "Security" lights are a perfect example. Most people don't realize that 80 to 90 percent of home burglaries occur during daylight. What type of suspicious activity could be worse than someone prowling around in the dark with a flashlight in order to commit a burglary? It is simply much less complicated to commit crimes during the daytime. Public awareness is the best deterrent — not "security" lighting.

Conservation is another good reason to reduce the incredible amount of unneeded outdoor lighting in use today. As a student in college physics I once had an opportunity to produce light from a hand-cranked generator. The resistance in the circuit was provided by a 20-watt light bulb. The amount of energy needed to produce those few feeble photons was astonishing. It would challenge the most athletic among us to keep the light on for an hour, let alone all year. An average mercury vapor "security" light consumes 400 watts, 20 times the small bulb I kept lit for a mere few seconds.

The country can no longer afford to waste energy. Bring this waste to the attention of your city council, talk to your neighbors, and practice energy conservation yourself. The result will be a healthier environment and a more beautiful night sky for everyone to enjoy. —
Tom Nirider, Port Orchard, Washington

Peter Leschak's article typifies the frustration felt by many amateur astronomers. But with a little tactfulness much of the unnecessary outdoor lighting (and the problems it causes) can be extinguished.

As a group of friends watched

[continued on page 12]

ALTER FOREVER YOUR SENSE OF SPACE AND TIME

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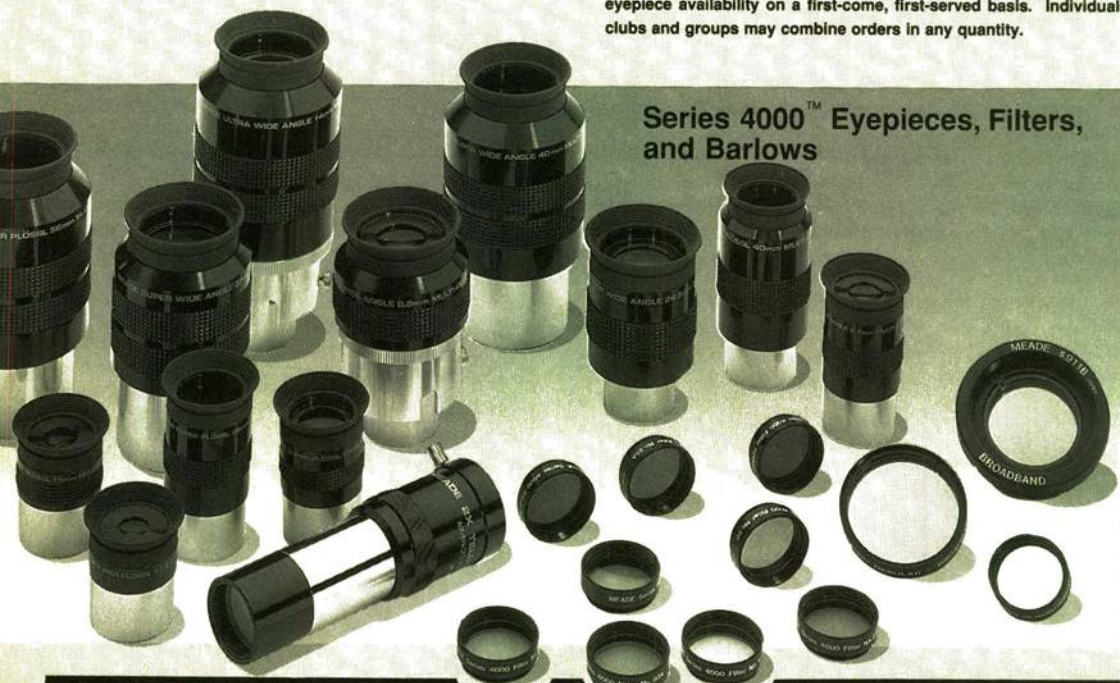
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#545: 8 x 50mm—(lower photo) Wide 5° field; coated achromatic objective; crosshair eyepiece. White tube. Ideal for telescopes of any aperture. See bracket below. **\$69.95** (4.28)

#544: 8 x 50mm—Same as #545, but in Meade blue. **\$69.95** (4.28)

#957: 9 x 60mm—(top photo) Collects 44% more light than 50mm; superior for faint objects; bracket below. **\$99.95** (4.68)

Bracket for 8 x 50mm: Fits Meade and Celestron SCT's, and other tubes from 7" to 20" diameter. **\$17.95** (2.79)

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Superb, fully multi-coated 11 x 80mm and 20 x 80mm Giant Binoculars. Ideal for wide-field deep-space observing. Rubber-coated bodies for rugged field use. BAK-4 prisms yield bright, sharp, high-contrast images. Hard carry case, tripod adapter included.

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#927: for .965" focusers.

#928: for 1.25" focusers.

#931 Hybrid: accepts 1.25" eyepieces, fits .965" focusers.

Specify model desired. each: **\$49.95** (2.79)

HOW TO ORDER

■ Prices shown are suggested USA mail-order retail prices and do not include any applicable sales taxes.

■ Suggested shipping and handling charges to the 48 states by UPS or US Mail shown in () next to each price.

■ Meade accessories may be ordered from any Meade Advanced Products dealer. The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:

ASTRONOMICS, Norman, OK.

Orders: 800-422-7876; Info.: 405-364-0858.

CALIFORNIA TELESCOPE CO., Burbank, CA

Orders: 800-843-4780; Info.: 818-505-8424.

CITY CAMERA, Dearborn, MI.

Orders: 800-359-5085; Info.: 313-846-3922

FOCUS CAMERA, Brooklyn, NY.

Orders: 800-221-0829; Info.: 718-436-6262.

LUMICON, Livermore, CA.

Orders: 800-767-9576; Info.: 510-447-9570.

SHUTAN CAMERA & VIDEO, Chicago, IL.

Orders: 800-621-2248; Info./IL: 312-332-2000.

Canada:

KHAN SCIENCE CENTRE, Toronto, Ontario.

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■ **Accessories and Components:** Meade Starfinder telescopes include high-performance components throughout: #71 Rack-and-Pinion Focuser (1.25") for smooth, backlash-free focusing of the image; a coated achromatic #637 6 x 30mm Viewfinder with crosshair eyepiece and 7° field, for quick object-locating; coated MA 25mm (1.25") eyepiece; strong, durable spiral-wound optical tube with attractive white finish; and cast aluminum mirror cell for accurate mounting and alignment of the primary mirror.

■ **Optional Accessories:** See the opposite page for some of the many optional accessories available. Additional systems, including the #55 Manual Declination Control, #43 Drive Corrector and #47M Dual-Axis Drive Corrector, are described in the Meade General Catalog.

A Meade Starfinder telescope opens up the skies to an extremely wide range of serious visual observing, to lunar and planetary photography, and even to limited deep-space photography. And every telescope is backed by the World's largest manufacturer of serious telescopes.

■ **Packing & UPS Shipping Charges** to any address in the 48 states: 6"--\$50; 8"--\$60; 10"--\$75.

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■ **The 1993 Meade General Catalog—\$3.00 postpaid—**

is available from any authorized Meade dealer or directly from Meade Instruments.

■ **For further information call Meade Instruments at 714-756-2291 or contact one of these authorized mail-order dealers:**

ASTRONOMICS, Norman, OK.

Orders: 800-422-7876; Info.: 405-364-0858.

CALIFORNIA TELESCOPE COMPANY, Burbank, CA.

Orders: 800-843-4780; Info.: 818-505-8424.

CITY CAMERA, Dearborn, MI.

Orders: 800-359-5085; Info.: 313-846-3922

FOCUS CAMERA, Brooklyn, NY.

Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.

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SHUTAN CAMERA & VIDEO, Chicago, IL.

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STARFINDERTM REFLECTING TELESCOPES

Meade Starfinder 6", 8", and 10" reflecting telescopes offer the finest values available anywhere. Standard equipment on all 3 models includes:

■ **Superb Optical System:** Includes a Meade hand-figured parabolic primary mirror that meets the theoretical limit of resolution for its aperture, with matching elliptical flat secondary mirror. Both mirrors multi-coated and made of fine-annealed Pyrex[®] glass.

■ **Precision Equatorial Mount:** Manufactured of virgin aluminum castings machined to tolerances of .001" or better, and placed atop a 4"-dia. pier with die-cast tripod legs, yielding rock-solid support for the optical tube assembly. The telescope moves effortlessly from object-to-object on precision bearing surfaces. Polar and declination shafts are

6" f/8
\$599.95

8" f/6
\$699.95

10" f/4.5
\$799.95

Starfinder 16: 16" f/4.5 \$2195.

See the Meade General Catalog for details.

Shown with optional Dual-Axis Drive Corrector.





8" Model 2080A:
\$1099.*

10" Model 2120A:
\$1379.*

Meade Standard Series 8" and 10" SCT's: advanced technology at economical pricing levels.

No other comparably-priced Schmidt-Cassegrains offer the optical and mechanical features of the Meade Standard Series:

■ **Optics:** The World's most recommended and largest-selling Schmidt-Cassegrain optics, warranted to be the finest available from any manufacturer. Razor-sharp imaging through both 8" and 10" models. Standard Series 8" and 10" SC optics are the exact same as used on Meade LX200 models.

■ **Mountings:** Highly stable, low vibration fork mountings designed for advanced applications such as long-exposure astrophotography, mountings that can carry more than *twice the payload* of competing small German-type mounts.

■ **Standard-Equipment Motor Drive System:** Not an add-on, but a *built-in 5.75" worm gear drive that is the most accurate available on any SCT in this price range.*

■ **Variable-Height All-Metal Field Tripods:** The finest tripods yet developed for SC telescopes, the ultimate in rigidity and low-damping time.

■ **Optional Systems:** Unlike competing German-mounted SCT's with small worm gears, Meade Standard Series SCT's permit almost unlimited growth potential—use the #46 Dual-Axis Drive Corrector for deep-space photography with the Off-Axis Guider system; #929 2" Diagonal with 2" Super Wide Angle eyepieces for breathtaking wide-field observing; and much more. *See the Meade catalog for details!*

□ For further information on Meade ED Apochromatic or Schmidt-Cassegrain telescopes, visit one of the hundreds of Meade dealer showroom locations throughout the USA; or contact one of the authorized mail-order dealers at left. Or call Meade Instruments at 714-756-2291.

4" Model 2045D:
\$699.*



4" Model 2045D: the Ultraportable Meade SCT

For the beginning astronomer the light-weight and easy-to-use Meade 2045D packs a powerful potential for serious observing. As a second telescope for the advanced amateur, the 2045D permits wide-ranging observations in locations inaccessible or inconvenient to larger instruments. Each telescope includes optics manufactured to the same high performance standards as larger Meade models. The DC drive system operates from a micro battery pack for convenient field use. Full accessorization is available for virtually any field application.

Specifications: Model 2045D—Complete with 4" f/10 Schmidt-Cassegrain tube assembly with super multi-coated optics; fork mount with setting circles, manual slow-motion controls, and locks on both axes; 12-volt DC pulse motor, spur gear drive system; AA battery pack (batteries are not included); tabletop tripod system; eyepiece holder/diagonal prism; coated MA 25mm (40X) eyepiece (1.25"); 5 x 24mm viewfinder. **\$699.**

Packing and shipping in the 48 states **\$40.**

Specifications: 8" Model 2080A—Complete with 8" f/10 Schmidt-Cassegrain optical tube assembly; fork mount with setting circles, manual slow-motion controls and locks on both axes; 5.75" worm gear motor drive system (115v/60Hz); eyepiece holder (1.25"); diagonal prism; coated MA 25mm eyepiece (1.25"); 6 x 30mm viewfinder; equatorial wedge; variable-height all-metal field tripod. **\$1099.**

Model 2080B—Identical to Model 2080A, but in addition with Super Multi-Coated optics. **\$1149.**

Packing & shipping on either 8" model in the 48 states: . . . **\$95.**

Specifications: 10" Model 2120A—Complete with 10" f/10 Schmidt-Cassegrain optical tube assembly; fork mount with setting circles, manual slow-motion controls, and locks on both axes; 5.75" worm gear motor drive system (115v/60Hz); eyepiece holder (1.25"); diagonal prism; coated MA 25mm eyepiece (1.25"); 8 x 50mm viewfinder; equatorial wedge; variable-height all-metal field tripod. **\$1379.**

Model 2120B—Identical to Model 2120A, but in addition with Super Multi-Coated optics. **\$1449.**

Packing & shipping on either 10" model in the 48 states: **\$125.**

□ *All prices shown are suggested USA mail-order retail prices, exclusive of sales taxes or credit card charges, if applicable.

□ The all-new 1993 Meade General Catalog—\$3.00 postpaid—is available from any authorized Meade dealer or directly from Meade Instruments.

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Orders: 800-422-7876; Info.: 405-364-0858.
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LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 510-447-9570.
SHUTAN CAMERA & VIDEO, Chicago, IL.
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ED APOCHROMATIC REFRACTORS

"Images through the Meade 6" ED/APO are absolutely stunning even by professional standards. Image contrast and definition are amazing. Quality and workmanship are flawless....color correction and contrast are simply better than any telescope I've ever used."

—O. H. Brettman, Past President, The Astronomical League, Huntley, IL

Meade complete ED Apochromatic Refractors include optical tube assembly with giant 2.7" rack-and-pinion focuser, equatorial mount, field tripod, 8 x 50mm viewfinder, giant 2" diagonal mirror, and Super Plössl 26mm eyepiece:

4" f/9 Model 102ED, complete	\$2195.
5" f/9 Model 127ED, complete	2795.
6" f/9 Model 152ED, complete	4495.
7" f/9 Model 178ED, complete	5495.
#1664 Electronic Drive System	375.
#1697 Computer Drive System	695.

Packing & shipping in the 48 states: 4"—\$105; 5"—\$125; 6"—\$185; 7"—\$215.

Meade Model 152ED: 6" f/9 ED Apochromatic Refractor. Shown with optional #1697 Computer drive System.

Meade super multi-coated ED apochromatic objective lenses yield ultra high resolution, high contrast images virtually free of any false color.

Ten or more internal light baffles effectively eliminate any stray light reaching the focal plane.

6" and 7" models include the LXD 700 Equatorial Mount and giant field tripod.

LXD 600 and LXD 700 equatorial mounts include 8 ball bearings (4 on each axis) and worm gear controls on both axes.

Meade Model 102ED: 4" f/9 ED Apochromatic Refractor. Shown with optional #1664 Electronic Drive System.

4" and 5" models include the LXD 600 Equatorial Mount and standard field tripod.

Standard accessories include 8 x 50mm viewfinder, 2" diagonal mirror, Super Plössl 26mm eyepiece.

Optional #1697 Computer Drive System has 4 drive speeds on both axes: 2x, 32x, 2° and 8° per second.

Press the keypad controller buttons of the #1697 Drive to move the telescope across the sky electronically. Enter any one of 747 standard objects (or one of 8000 optionally available library objects), press GO TO and the telescope slews directly to the object.

Enter in the keypad the RA and Dec of any object, press GO TO, and the telescope automatically slews to the object at 8° per sec.

Optional #1664 Electronic Drive System has 2 drive speeds on both axes: 2x, 32x.

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December's lunar eclipse with me, for example, a neighbor suddenly blasted us with floodlights. After politely informing her of the nuisance, she apologetically explained she had thought the light would help us see better! I gracefully declined this well-intentioned gesture and invited her family over to watch the eclipse. In the restored darkness, the families enjoyed the sky together. — *Bob Schepis, Mullica Hill, New Jersey*

Another Observational Breakthrough

I enjoyed reading the piece by Dean Grantham called "An Observational Breakthrough for Amateurs" in Viewpoints (January 1993). I was equally impressed to read several responses to this article in Letters (March 1993). It's refreshing to see that some carefree stargazers are still out there and aren't overrun by the hard-core, serious types.

Coincidentally, I've discovered another observing breakthrough for amateurs. One day I snuck a 2.4-inch refractor into a planetarium show. It was wonderful. I have been able to see the stellar disks of Betelgeuse, Rigel, Sirius, and other bright stars. With resolution like this, just imagine what a big Dobsonian would do! — *Richard S. Andrews, Niles, Ohio*

If This Is Wednesday, It Must Be Toutatis

Thanks for publishing the images of the binary asteroid Toutatis ("Toutatis Seen with Radar" by Richard Talcott, April 1993). Just imaging that pair of objects hurtling through the solar system is wonderful. Each day we find our universe more interesting, complex, dynamic, and hazardous than we previously imagined.

I did some calculations using simple approximations (spheres with a density of 3 grams/cc). The pieces of Toutatis have masses of about 25 and 100 billion metric tons, and the gravitational force between them is equal to 15 million tons. To move them apart would take the force of 4,000 Saturn rockets.

When these fragments came together — perhaps after the breakup of a parent body — it must have been reasonably gentle. However, they must have had some rotational energy that was probably dissipated by grinding at the area of contact. If the crushing strength of the stony (?) material is about 10,000 pounds per square inch, the zone of contact is at least 60 meters across.

It would be interesting to know if the

two components roll, twist, or bump, but I'd better leave that calculation to someone else. — *William Reid, Vancouver, Washington*

Memorable Meteor

On Sunday, September 13, 1992, I saw the meteor of a lifetime. A little after 9 p.m., I was facing east when suddenly a bright flash appeared behind me, casting shadows on the ground. A fraction of a second later I looked up and was able to see the last part of the trail.

This object had a much wider trail than most meteors do and reminded me of a firework. — *Marvin Cooper, Hiram, Ohio*

Owl Observatory

I greatly enjoyed your series published last year on the building of Owl Observatory (April, May, and June 1992). In fact I enjoyed it so much that I decided to build a copy of Owl Observatory for myself.

I contacted two local carpenters, worked with them in constructing the



Bill Chase

Chickamauga's Owl Observatory

observatory, and have recently ordered a large Dobsonian telescope to place inside the structure.

Thanks for helping to make my observatory plans come true. — *Bill Chase, Chickamauga, Georgia*

Correction

The article "All in the Family" by Dan Durda (February 1993) contained a reference to research on the Williams and Zappalà asteroid families by Jeff Bell. In fact, James Granahan of the University of Hawaii was the principal author of that study and Bell was coauthor. □

ASTRONOMY welcomes suggestions and additional information about articles and astronomy in general. Send your letters to ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187. Letters may be edited for length and clarity.

WHY ASTRONOMY CLUBS?

by Robert Bunge

Through the zoom eyepiece of the 2.4-inch refractor, I saw a round reddish ball of light. The edges were slightly fuzzy. During fleeting moments I could make out hazy dark areas. I had done it — I had seen surface features on Mars.

I tried, without luck, to match some of those dark markings with a map of Mars from a borrowed book. In fact, everything was borrowed — the telescope, the eyepieces, and the books. A few weeks before, while browsing in my high school library, I had come across a small book on telescopes, Henry Paul's *Telescopes for Skygazing* and had gotten hooked. I read the book cover to cover at least fifty times. I was completely fascinated by the pictures of the Moon. You can see craters on the Moon? Soon I harassed a friend who owned an unused telescope until he let me borrow it. The round reddish ball with fuzzy edges was the reward for my diligence.

So the next evening I tried again. Even though it was clear, Mars appeared smoother, without the features I had seen the night before. I was pretty disappointed. The next week I heard about the upcoming meeting of a local astronomy club, the Columbus Astronomical Society. It would be exciting to meet people with similar interests. They might be able to help me with my Mars observing. But I was also worried. Would they accept a high school kid? The name of the group sounded so, well, scientific.

When I walked into the meeting room, I found myself among 20 or so strangers, so I took a seat in an empty row toward the back of the room. Following a short business meeting, a member of the group gave a talk on the astrophotography he was doing at nearby Perkins Observatory. Afterward, being somewhat interested in photography myself, I summoned up my courage and approached him with some questions. This was a turning point. Did he make the telescope? (No) What type of developer was he using? (D-19) Could I take a look at some of his prints? (Yes) Within minutes, I was invited to the home of one of the club members for a tradition — pizza — as the members worked on the grinding of a 16-inch telescope mirror.

The learning curve was steep. Within

minutes I had discovered blanks, tools, rouge, pitch, polish, figuring, and testing. They even let me push the piece of glass on the top of the mirror back and forth a few times. Me, a complete novice. The evening ended with an invitation to come to the observatory the following weekend.

A few nights later, I found myself standing next to the dome of the 32-inch reflector at Perkins Observatory. With incredible patience, one of my new friends pointed out constellations one by one. With this help, I saw all sorts of mythical figures in the sky that I had read about in school. I saw the pale glow of the Milky Way for the first time. And then I found myself looking at Mars with the 32-inch. Wow! From 2.4 inches to 32 inches in two weeks. Through the 32-inch, Mars appeared completely different than it did in my backyard views. I could see the polar cap easily, although I still had some difficulty identifying all the dark markings.

It took me three or four years to realize what had happened during my first disappointing look at Mars from my backyard. I hadn't even been looking at Mars. Instead, I had pointed the little refractor at the star Capella when it was low in the northeast sky. With the eyepiece racked somewhat out of focus, the slightly reddened star shimmered in unsteady air, producing variations across the out-of-focus disk that looked, to my untrained eye, like faint dark markings.

Solving this Mars mystery wasn't all I learned with the help of my new friends in the society. A few months after I joined, the overseers of the 16-inch mirror project, who had apparently decided that I wasn't going to drop the grinding tool and break their mirror, let this high school kid do some of the dirty work. I was thrilled. Here was a chance to show them that I was truly interested and worthy of being taught. The work sessions led to more trips to the observatory, where I learned to operate the telescope and helped take some astrophotos. Things were definitely looking up.

Soon after high school, I left the comfort and security of home for the adventure of the U. S. Navy. I was assigned to an aircraft carrier and was able to use the skills and knowledge passed on to me by Columbus Astronomical Society

[continued on page 16]

FOR SALE — 10" Meade (1990) telescope, tripod, wedge, elec. Dec., full solar filter, ECC, extras. \$2,000 or trade for 8" Schmidt camera. Contact Patrick McGuire, 3124 Fallowfield Drive, Diamond Bar, CA 91765. Phone (909) 595-5953.

WANTED — Polish amateur astronomy club is looking for members. If you write or speak Polish and are interested in astronomy, let us know. Contact Daniel Kononczuk, 9 Leslie Place, Irvington, NY 07111 or Gracyon Wozniak, 12 B. Lucerne Gus, Edgewater 6027 Australia.

WANTED — Twenty-four-year-old Portuguese interested in astronomy, space exploration, and related subjects would like to correspond with those with similar interests. Contact Miguel Matos, Av 22 de Dezembro Nº23 - 8ºdto, 2900 Setúbal, Portugal.

FOR SALE — Astronomy programs for IBM compatibles. Available from a private collection of over 500 space science programs and databases. Programs include telescope making, astrophotography, planetarium, satellite tracking, space exploration, astrophysics, and other related subjects. For a free catalog and disk, send a SASE to Joe Dumanov, 181 Springbrook Trail, Sparta, NJ 07871. Phone (201) 729-9508.

FOR SALE — Celestron 90, factory dew shield, erect image viewfinder, 45° diagonal, etc. Mint condition. \$285. Contact David Clemens, 251 Parkiomen Avenue, Schwenksville, PA 19473. Phone (215) 287-7716.

WANTED — I am seeking a desktop-sized model of the Voyager spacecraft made of metal or plastic only. Contact Matt Harrington, 7640 Chadds Landing Way, Manassas, VA 22111-1770.

FOR SALE — Celestron C8 telescope with wedge and equatorial mount. \$1,000 or best reasonable offer. Contact Roy Malahowski, 218 S. Garney Avenue, Bakersfield, CA 93309. Phone (805) 833-1143.

FOR SALE — One rarely used C8 telescope, complete with carrying case and additional lenses. \$1,250. Contact Steve Zlotnik (414) 265-4676 or (414) 964-9444.

FOR SALE — 13.1" Odyssey I reflecting telescope, one year old, 32mm Erfle, and Telrad base. \$690. Must pick up in Florence, South Carolina. Contact V. Hinson. Phone (803) 662-3200.

WANTED — Philadelphia couple seeks correspondence with amateur astronomers in Australia. We plan to tour in November, 1993. Objective: witness transit of Mercury (11/6), view partial eclipse (11/13), and see the southern Milky Way. Contact Mitch Berger, 269 W. Walnut Lane, Philadelphia, PA 19144.

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MEADE APOCHROMAT ED REFRACTORS



Meade 6" f/9 Model 152ED Refractor shown with #1697 Computer.

See the Meade ad in this magazine for full specifications and product descriptions. ED = Extremely low dispersion glass which yields color-free virtually perfect images. PPEC = Permanent Periodic Error Correction "Smart Drive".

Model 102 ED 4" f/9 Apochromat & mount (add \$105 P&S) \$2195
Model 127 ED 5" f/9 Apochromat & mount (add \$125 P&S) \$2795
Model 152 ED 6" f/9 Apochromat & mount (add \$185 P&S) \$4495
Model 178 ED 7" f/9 Apochromat & mount (add \$215 P&S) \$5495

Medium format adapters Mamiya 645, \$98; Pentax 6X7, \$98
 Med. format EASY-GUIDER™; Mamiya 645, \$298; Pentax 6X7, \$298

DRIVE SYSTEMS

*1664 Electronic Drive with PPEC & 2X, 32X slewing system \$375
 #1697 Computer Drive, 747 object computer memory, automatic slewing to desired object \$695
 8,000 Object CNGC Library \$99 Polar alignment finder \$99

OPTICAL TUBE ASSEMBLIES (OTA)

Model 102 ED/OTA 4" f/9 OTA only (add \$55 P&S) \$1045
Model 127 ED/OTA 5" f/9 OTA only (add \$60 P&S) \$1595
Model 152 ED/OTA 6" f/9 OTA only (add \$100 P&S) \$2295
Model 178 ED/OTA 7" f/9 OTA only (add \$120 P&S) \$3250

Cradle ring assem. 4" (4 1/2" OD tube) \$145; 5" (5 1/2" OD tube) \$159
 Cradle ring assem. 6" (7" OD tube) \$189; 7" (8" OD tube) \$240

EQUATORIAL MOUNTS

LXD 600 mount and standard field tripod (add \$60 P&S) \$1295
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NOTE: Add the indicated packing and shipping (P&S) costs to each telescope for insured UPS shipment to your door.

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 24.5mm Super Wide Angle \$170
 32mm Super Wide Angle (2") \$240
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 4.7mm Ultra Wide Angle \$155
 6.7mm Ultra Wide Angle \$188
 8.8mm Ultra Wide Angle (1 1/4") \$230
 14mm Ultra Wide Angle (1 1/4") \$270

Shipping charges of 1-2% are extra.
 *Plossl test, "SKY & TELESCOPE," p490-492, May 1988

MEADE LX100 & LX200 SCHMIDT-CASSEGRAINS



NEW Meade 8" LX200 Telescopes

See the Meade ad in this magazine for full specifications & details. LX100 Drive, 2X, 32X speed control with PPEC (Permanent Periodic Error Correction "Smart Drive") & dual-axis hand controller. LX200 Drive, Full electronic control with PPEC, 747 object computer memory and automatic computer controlled slewing to desired object. NOTE: A wedge is not needed for visual observing with the LX200 Drive.

8" LX100 Schmidt-Cassegrain with wedge (add \$105 P&S) \$1795
8" LX200 Schmidt-Cassegrain with computer (add \$105 P&S) \$2195
Wedge for photographing with 8" LX200 \$110
10" LX100 Schmidt-Cassegrain w/wedge (add \$145 P&S) \$2595
10" LX200 Schmidt-Cassegrain with computer (add \$145 P&S) \$2495
Super Wedge for photographing with 10" LX200 \$395
 8,000 Object CNGC Library \$99

OTHER SCHMIDT-CASSEGRAINS

NEW! SSC-8, 8" Schmidt-Cass on LX200 mount (add \$105 P&S) \$1395
NEW! SSC-10, 10" Schmidt-Cass on LX200 mount (add \$125 P&S) \$1695
NEW! SSC-12, 12" Schmidt-Cass on LX200 mount (add \$195 P&S) \$3850
NEW! SSC-14, 14" Schmidt-Cass on LX200 mount (add \$245 P&S) \$4495
Meade 2045D 4" f/10 with motor drive (add \$40 P&S) \$659
Meade 2080B 8" f/10 with tripod, wedge, MCOG (add \$85 P&S) \$1149
NEW! Model 2120B 10" f/10 w/wedge, tripod, MCOG (add \$125) \$1449

PHOTOGRAPHY ACCESSORIES

LUMICON Cassegrain EASY-GUIDER f/6 or f/10 \$225
 LUMICON Giant EASY-GUIDER for 10" f/5-f/10 operation \$395

MEADE STARFINDERS



New 8" f/6 Meade Starfinder telescopes

See the Meade ad in this magazine for full descriptions and technical specifications for 6" to 16" Starfinders. These are complete telescope systems with motor drive, mount, finderscope and 25mm (=48X) eyepiece.

6" f/6 Starfinder (add \$50 P&S) \$569
8" f/6 Starfinder (add \$60 P&S) \$649
10" f/6 Starfinder (add \$75 P&S) \$759
16" f/6 Starfinder 16 (ship. freight COD) \$1995

*All Starfinder telescopes shipped directly from Meade to the purchaser. Please add the indicated shipping charge to the price. LUMICON showroom prices are \$96 higher.

ACCESSORIES

LUMICON carries the full line of Meade accessories. See the Meade ad in this magazine for detailed prices and descriptions.

Meade #43 Single axis drive corrector \$99
LUMICON DX200 Dual-axis drive cor. \$249
Meade 47M Dual-axis drive corrector \$399
LUMICON DX28P Dual-axis drive corrector with built-in battery pack \$299

LUMICON® SKY VECTOR™

Higher Performance — Lower Price

LUMICON, 2111 Research Dr., #5, Livermore, CA 94550

(510) 447-9570 FAX (510) 447-9589

LOW PRICE—from \$399

LUMICON SKY VECTOR FEATURES:

- "GUIDE" mode leads you to object
- Digital right ascension readout to 1 min.
- Digital decl. readout to 10 arc-min.
- 4000 pulse (0.09" accuracy) encoders
- Polar alignment **not required!**
- Motor drive **not required!**
- Just sight two stars to align!
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080.
- **No need** to enter latitude, longitude, etc.

SKY VECTOR I™ \$399

NEW! With over 220 object memory including the 110 Messier and 58 best NGC objects.

SKY VECTOR II™ \$499

IMPROVED — Planets, Over 3,700 Objects! With size, magnitude and full visual description.

NGC SKY VECTOR™ \$699

IMPROVED!—5500 Additions / Corrections

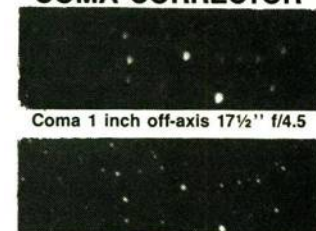


Improved NGC SKY VECTOR with over 12,000 object memory including the planets, complete, corrected NGC catalogue, IC catalogue, P&K planetary catalogue, & much more!

Specify Telescope Type: Meade 2045, 2080, 2120, C-8, C-11, Odyssey 8, 10, 13, 17 1/2, Alt-Azimuth.

Ultima 8, 11 add \$25, C-14 add \$75

COMA CORRECTOR



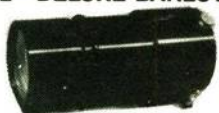
Coma 1 inch off-axis 17 1/2" f/4.5

Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. It threads into LUMICON 2" EASY-GUIDERS for effortless installation. This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Clear aperture = 1.8".

LUMICON 48mm Coma Corrector/Field Flattener Lens \$285.00
 LUMICON 2" EASY-GUIDER \$169.50
 2" EASY-GUIDER (Mamiya 645) \$199.50
 2" Adapter for Pentax 6x7 \$129.00
 2" Adapter for Hasselblad \$229.00
 2" Adapter for Bronica SQ-A \$175.00
 2" Extension for viewing \$26.00

2" DELUXE BARLOW



1.8x Multiplier Lens (2" Barlow)

LUMICON 1.8x Multiplier Lens (2" Barlow) \$235.00

LARGE UV/DUST SEAL



Protect the optics of your 8-14" Schmidt-Cassegrain with a UV/Dust Seal. Simply thread it onto the rear cell, then attach all normal accessories. The large size fits Meade 2120, Celestron-11 and -14 & has a high quality multi coated (removable) 72mm UV filter.

Deep-Sky Filter/Dust Seal for C-8, 2080 \$119.50
 UV/Dust Seal for Celestron C-8 \$39.00
 UV/Dust Seal for Meade 2080, 2045 \$39.00
 UV/Dust Seal (large) for Meade 2120 \$89.50
 UV/Dust Seal for Celestron-11, -14 \$89.50

NEW! LOW PROFILE HELICAL FOCUSERS

FROM \$59.50



LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1 1/4"-1 1/2" above the telescope tube. Use the 1 1/4" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.

Select your desired base-plate shape!

Flat, 7" OD, 9 1/2" OD, 12 1/2" OD, 16" OD, 21" OD.

LUMICON 1 1/4" Helical Focuser \$59.50
 LUMICON 2" Helical Focuser 1 1/4" high \$65.00
 LUMICON Non-rotating Helical Focuser \$129.00
 2" Astro Systems focuser, only 2" high \$139.00
 3 handles for non-rotating focuser \$12.95
 2" f/14" adapter w/48mm filter threads \$20.00
 2" LUMICON EASY-GUIDER \$169.50

LUMICON 50mm, 80mm SUPER-FINDER™



Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra.

1 1/4" 50mm Finderscope \$59.50, right-angle \$59.50
 1 1/4" straight-thru 80mm SUPER-FINDER \$169
 1 1/4" right-angle 80mm SUPER-FINDER \$179.50
 1 1/4" right-angle version, w/star diagonal \$209
 25mm Cross-hair 1 1/4" eyepiece (12X) \$39
 Large mounting rings for 80mm Finder \$55
 1 1/4" Star Diagonal \$39, Mounting Brackets, \$39.50
 1 1/4" 45° diagonal for correct left-right views \$52.44

LOTS OF ADAPTERS

2" adapter for C-8, Meade 2080, etc. \$26.00
 2" adapter for C-80, C-100 refractor \$39.50
 2" adapter for C-70, C-80F, C-100F fluorite \$39.50
 2" adapter for C-6, Comet Catcher, Meade 312 \$30.00

EXTENSION TUBES

1" long 1 1/4" OD thread-in extension \$12.00
 2 1/2" long extension (holds 1 1/4" filters) \$16.00
 4 1/2" long extension for 1 1/4" eyepieces \$25.00
 3" long extension for 2" eyepieces \$26.00
 2" long extension for 2" eyepieces \$26.00

VIEWING ADAPTERS

2 7/16" reducing bushing, threaded 48mm \$20.00
 2" T-thread adapter, threaded 48mm \$25.00
 T-thread/1 1/4" adapter \$25.00
 F10 2" or 1 1/4" eyepiece viewing adapter for Giant Easy-Guide \$39.50
 Low profile star diagonal eyepiece holder \$16.00
 Meade 2" Diagonal/Giant Easy-Guide \$39.50
 *Threaded to hold 48mm filters.

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LUMICON Carries a full line
of telescopes & accessories.
Fast Delivery, competitive
prices.

LUMICON FOR HIGH PERFORMANCE

ASTROPHOTO OF THE MONTH



Galaxy NGC 4631 and companion NGC 4627 in Canes Venatici. 60 minute photo by Eraldo Guidolin (in Padova, Italy) using an 8" f/10 telescope, a LUMICON Cassegrain Easy-Guider at f/6 and hypered 2415 film. Mr. Guidolin stated, "With your Cassegrain Easy-Guider I have taken hundreds of perfect ly guided high quality photographs."

TELE VUE™ PLOSSL SALE — \$79

TELE VUE EYEPIECES



Genesis 4" f/5.4 element fluorite ... \$1595
Pronto 70mm f/6.4 apochromat w/2" diagonal ... \$798
Complete Equatorial Mount ... \$795
Motor Drive for above mount ... \$239
7.4, 10.4, 13, 17, 21, 26mm Plossl 50° ... \$79
1.8x or 2.5x Tele Vue Barlow Lens ... \$89
2" Giant Barlow - 2x ... \$189
32mm Plossl, widest true field in 1 1/4" ... \$109
55mm 2" Plossl, widest possible field ... \$219
15mm Wide-Field, 1 1/4" eyepiece, 65° ... \$135
19mm Wide-Field, 1 1/4" eyepiece, 65° ... \$145
24mm Wide-Field, "Rich-Field" 65° ... \$169
32mm Wide-Field, 2" eyepiece, 65° ... \$239
40mm Wide-Field, "Rich-Field" 65° ... \$299
4.8mm Nagler, 82° field, 1 1/4" eyepiece \$149
7mm Nagler, 1 1/4" eyepiece, 82° field ... \$189
9mm Nagler, 82° field, 1 1/4" or 2" ... \$219
11mm Nagler, 82° field, 1 1/4" or 2" ... \$235
13mm Nagler, 82° field, 1 1/4" or 2" ... \$249
12mm Nagler, Type II, 82° 1 1/4" / 2" ... \$249
16mm Nagler, Type II, 82° 1 1/4" / 2" ... \$289
20mm Nagler, Type II, 82° 2" only ... \$340
1 1/4" Paracorr Visual Coma Corrector \$159
2" Paracorr Visual Coma Corrector ... \$249
NEW! 22mm Panoptic 1 1/4" / 2", 68° ... \$249
NEW! 35mm Panoptic 2", 68° field ... \$325

NEW! ENHANCED ALUMINUM DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

LUMICON 1.3" & 2.1" enhanced aluminum
diagonal mirrors & 1 1/4" star diagonal.

The new LUMICON diagonal mirrors have a special enhanced aluminum coating with a protective overcoating for long life. Visible reflectivity is 94-96% compared to 86-89% for standard aluminum coated mirrors. The extra 5-10% transmission is like adding up to an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32" \$39.50 1.52" \$45.00 1.83" \$49.50
2.14" \$59.50 2.60" \$75.00 3.10" \$99.50

ENHANCED ALUMINUM STAR DIAGONAL

90° star diagonals with 96% reflectivity enhanced aluminum mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

1 1/4" (1.32" mirror) ... \$99.50
2" (1.83" mirror) (see photo above) ... \$159.00

ADJUSTABLE PIGGYBACK MOUNT



The LUMICON adjustable piggyback mount is ideal for telescopes of 8-16" aperture. It permits both vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER™, large telephoto lenses and small telescopes up to about 5 lbs. LUMICON Adjust. Piggyback Mount \$59.50
Specify telescope size: 6", 8", 10", 11", 14", 16"

H-ALPHA PASS FILTER



Yields spectacular contrast gains in B&W photograph with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) Filter.

Specify Lens Size	H-Alpha (MV)
46, 48, 49mm	\$49.00 \$39.00
52, 55, 58, 62mm	\$59.00 \$49.00
67, 72, 77mm	\$69.00 \$59.00
82mm	\$79.00 N/A

Hypered 2415 film, 36 exp ... \$10.95, \$3/\$29

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LUMICON FILTERS — BEST IN THE WORLD!

"The LUMICON OIII proved to be our favorite... It gave the greatest contrast gain."
ASTRONOMY February 1991

AMAZING OIII FILTER™



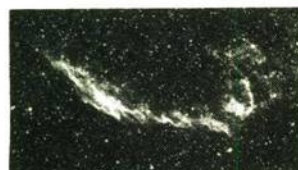
Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

The ultimate in filter performance! The Lumicon Oxygen-III Filter has a contrast twice as high as the high performance Lumicon UHC Filter™. Use the Oxygen-III Filter for observing the very faintest planetary and diffuse emission nebulae. Also gives incredible views of bright nebulae (like M-27, M-17, etc.) from urban locations. Bandpass is 11nm, transmission is 90-96% for both O-III lines at 496nm and 501nm.

SEE THE HORSEHEAD!



Horsehead Nebula in Orion. This faint nebula is seen best with a LUMICON H-Beta Filter. Photo by J. Marling using a Deep-Sky Filter.



"I CAN SEE THE VEIL NEBULA!"

Rich Zepernick saw the Veil Nebula for the very first time with a LUMICON UHC Filter. He stated, "It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters!"
Rich Zepernick, Cresskill, NJ

DEEP-SKY FILTER™

BEST for Astrophotography!

"Stunning is all I can say," says noted astrophotographer Jack Newton. Great for BOTH color and black and white photography.

BEST WIDE-BAND FILTER!

"Based on our tests we'd recommend a LUMICON Deep-Sky and Oxygen-III as complementary filters. The LUMICON Deep-Sky Filter clearly had the best contrast for reflection nebulae."

Astronomy, Feb. 1991

	Premium*
0.96" LUMICON DEEP-SKY Filter threads into most 0.96" eyepieces	\$59.50
1 1/4" LUMICON DEEP-SKY Filter threads into most 1 1/4" eyepieces	\$79.50
48mm LUMICON DEEP-SKY Filter (1.7" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS	\$119.50
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	\$119.50
72mm LUMICON DEEP-SKY Filter (62, 67, 77mm adapter, \$8)	\$299.50
2" Rear Cell Filter, fits SCT's	Deep-Sky, \$119.50 UHC, O-III, H-Beta, \$199.50
1 1/4" LUMICON UHC Filter threads into most 1 1/4" eyepieces	\$59.50
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	\$199.50
Set of both premium DEEP-SKY and UHC Filters (Save 11%)	1 1/4" \$159.50, 48mm \$279.50
LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. 1 1/4"	\$99.50, 48mm \$199.50
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm O-III lines	1 1/4" \$99.50, 48mm \$199.50
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm	\$6.95
Universal adapter for 1 1/4" filters. Adapts the 1 1/4" filters to any 1 1/4" eyepiece	\$16.00
Universal adapter for 48mm or 2" filters. Allows use of any 1 1/4" eyepiece	\$20.00

*Premium filters are currently the best in the world. All Lumicon filters include individually measured transmission data.

DEEP-SKY ASTROPHOTOGRAPHY

SR-V 3200 NEW FILM

FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15x film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

U.S. Patent 4,473,636

MAKE YOUR OWN HYPERED FILM

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds ... \$325



MODEL 600 HYPER-KIT (See photo) Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates ... \$395

MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller ... \$595

Temperature controller for any HYPER-KIT ... \$65

Electric Vacuum Pump, Model R-10 \$325

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All LUMICON EASY-GUIDER™ off-axis guiders have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars.

Specify Camera and Telescope type.

U.S. Patent 4,448,500

NEWTONIAN EASY-GUIDER™

Full aperture. Installs in seconds. Specify 2" or 1 1/4".

NEWTONIAN EASY-GUIDER ... \$169.50
3X Relay Diagonal (see photo) ... \$89.50
Illuminated reticle eyepiece system ... \$99.50
Guider for Hasselblad \$350, Mamiya 645 \$199
Pentax 6X7 add \$119; Pentax 645 add \$139

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Cymanax-8. Includes 50mm achromatic lens for f/5.8 operation—3X shorter exposures! Superb rich field viewing, too!

CASSEGRAIN EASY-GUIDER ... \$225.00
Adapter for Hasselblad \$198, Mamiya 645 \$98
Pentax 6X7 add \$119; Pentax 645 add \$139

GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. Also yields unmatched Rich-Field viewing.

GIANT EASY-GUIDER ... \$395.00
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE \$20) ... add \$99.95
Adapter for Hasselblad \$229, Mamiya 645 \$129
Pentax 6X7 add \$129; Pentax 645 add \$149

WHAT DO YOU NEED?

1. Illuminated reticle eyepiece ... \$99.50
Lumicon 12mm eyepiece system has adjustable LED illumination, dual crosslines, battery pack.
2. Cable release for long exposures ... \$9.95



3. LUMICON Digital Drive Corrector . \$249

Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 30Hz/90Hz variable output controls telescope drive. 60Hz digital reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Dec. reverse switch for Newtonians.
Declination motor (state telescope) ... \$109
Variable dec. speed drive w/built-in 5AH battery \$299



HYPERSENSITIZED FILM

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.). No C.O.D.s.

Film Type, 35mm	Exposures	Price
2415, Ultra-fine B&W, red sens.	36	\$10.95
SR-G3200, fastest of all, color neg	24	\$13.95
Kodak Ektar 1000 fast, fine grain	24	\$12.95
Fuji HG400 fine grain color neg.	12	\$10.95
3M 1000, fastest slide film	12	\$12.95
Fujichrome RD100, fine grain slide	24	\$12.95
D-19 B&W Developer	1 gal.	\$6.95

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Introducing **VE MINITRAK**. The most compact, state of the art, variable speed drive corrector / power inverter available. The digital quartz tracking indicator gives you precise - no guess - speed control for worry free observing or astrophotography. The compact unit fits comfortably into the palm of your hand for easy guiding. **VE MINITRAK** comes with a D.C. power cord for plugging into a 12 volt D.C. power source. Call or write for free catalog. Only \$99.95 plus \$6 S&H (IL residents add 7% tax)

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members to explore the southern skies with a pair of binoculars. Even though this was great fun, I missed observing with my friends. I missed sharing with them the joy of discovering novel and exotic skies and objects.

Five years after entering the Navy I returned to Ohio for college. Although a few familiar faces were still around, for the most part I found new people at the next CAS meeting. In some respects it was like being at the bottom of the ladder once again. Nonetheless I dove in and started to make new friends. Before long I was active in the group and later served a term as its president.

I've listened to people who complain about astronomy clubs. Clubs can be cliquish. People can be selfish. And some people are power hungry (I never have liked the politics in some clubs). In some cases, I've seen persons ostracized unless they bought the right equipment, said the right things, and paid their dues — and I mean actions, not money. Officers of all clubs need to recognize these problems and take steps to correct them. But in my eyes, clubs can serve a couple of very important purposes.

First, they allow people with similar interests to meet and discuss astronomy, deep-sky observing, mirror making, telescope making, and any other related subjects. I probably could have learned about the sky from books and magazines, but I wonder if I would have stayed with the hobby without the help and encouragement of my friends in the CAS.

Second, clubs allow amateurs to combine their skills on projects that otherwise might not be done — like organizing a successful star party, building an observatory, making a telescope, or finding a good observing site far from light-polluted skies. CAS built a 16-inch telescope and scouted out and established dark-sky observing sites across the state.

Finally, clubs help bring astronomy to the public. CAS formed what promises to be a long-lasting public education program with Perkins Observatory and local universities. And while this might have been achieved by individuals, the group effort made it easier and gave the program far greater reach. Over the coming years, this program promises to bring the wonder of astronomy to thousands of children and adults. And in so doing help to reinvent the hobby with a whole new generation of avid stargazers.

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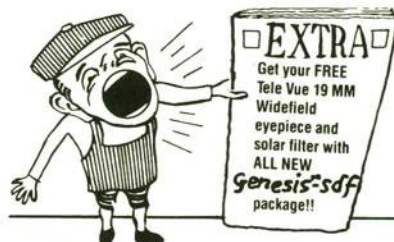
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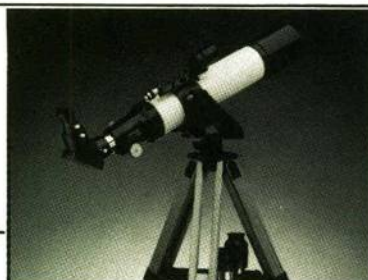
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Wholesale Optics of Pennsylvania — your Tele Vue dealer for the '90's is pleased to offer the "Complete Genesis Observing System"

**ALL NEW
Genesis™ sdf +
GIBRALTAR MOUNT +
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TELE VUE EYEPIECES +
SOLAR FILTER =**



Comfortable, Convenient, Quality observing

The high quality and proven versatility of Tele Vue's NEW **Genesis SDF** provides you with a uniquely, versatile scope without the hassle and cost of multiple instruments. The addition of new, special dispersion glasses, combined with fluorite lens Genesis SDF deliver widefield views of the Milky Way (up to 10 full moons across), take sharp, high contrast views of the moon, planets and sun. Enjoy spectacular views of nature's daytime wonders . . . right in your own backyard. And, Tele Vue's new, super, adjustable **AIR CHAIR** is a must for viewing comfort. **WHOLESALE OPTICS OF PENNSYLVANIA'S EXCLUSIVE INTRO PACKAGE** Purchase Genesis SDF + Gibraltar + Air Chair and we'll throw in a full aperture glass solar filter and a genuine Tele Vue 19 MM Widefield eyepiece — absolutely free!

P.S. Offer also applies to standard Genesis when purchased with package (while supplies last).



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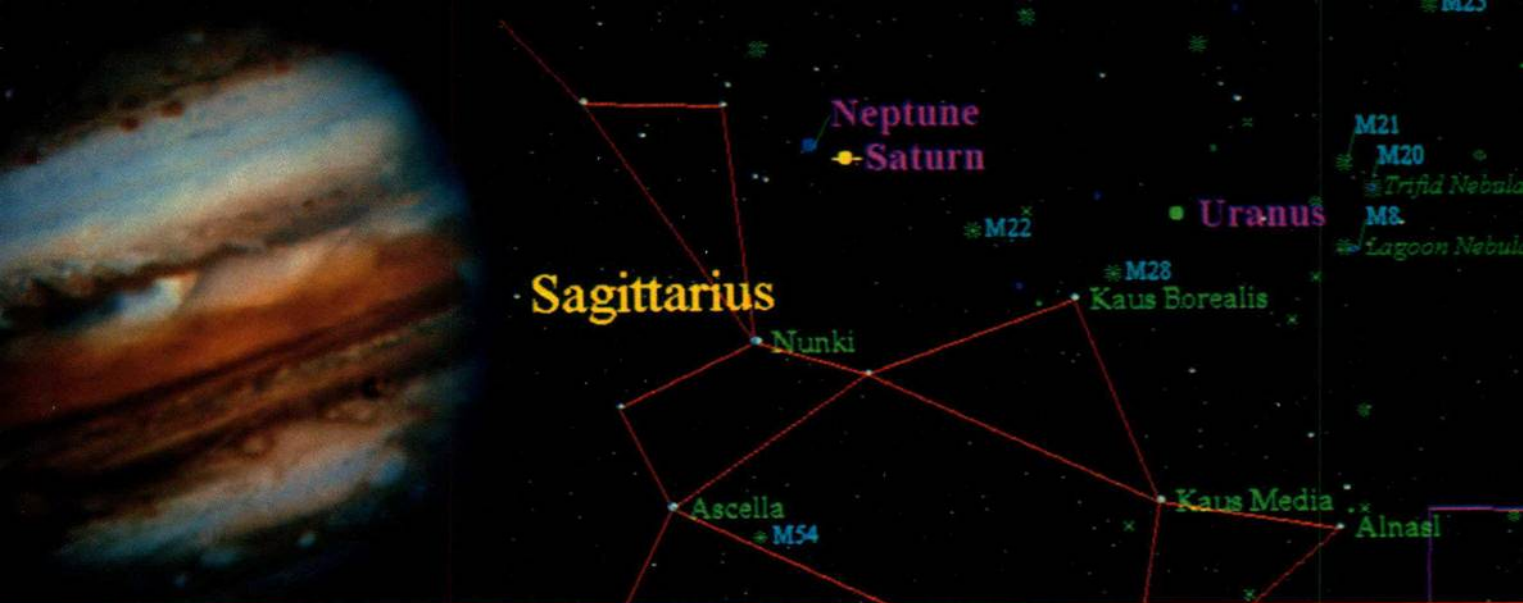
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\$15.00 to Australia

\$18.00 to New Zealand

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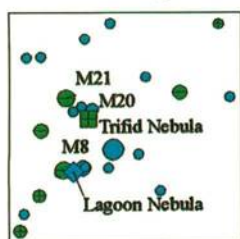
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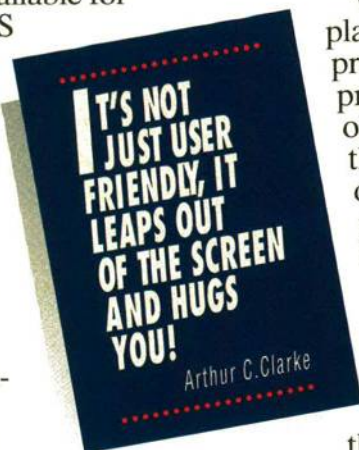
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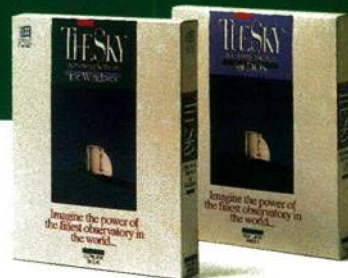
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CHAOS IN THE SOLAR SYSTEM

The orbits and axial spins of the planets are relics of the motions of the gas cloud from which the Sun and planets formed. Astronomers have long hoped that studies of the planets' spins could help them explore the early history of the solar system. Now two research groups have found that at least one trace of our past, the inclination of planetary spin axes, is lost because of large random, or chaotic, variations due to the gravitational pulls of other planets.

Jihad Touma and Jack Wisdom of the Massachusetts Institute of Technology investigated the change in the inclination of Mars' spin axis over the last 80

million years. They used a computer model of the orbital and rotational motions of the planets and found that Mars' inclination has varied irregularly from 11° to 49° (presently it's 25°). Planetary scientists had hoped that studies of the Red Planet's inclination would shed some light on how climatic changes might have created the layered deposits in the planet's polar regions. But Touma and Wisdom's results published in the February 26, 1993 issue of *Science* show that the history of changes in Mars' inclination is basically unknowable.

Earth also experienced random variations in its inclination, but the Moon's

gravity stabilized Earth's spin axis so it varies by only one or two degrees. That's the finding of J. Laskar, F. Joutel, and P. Rebutel of the Bureau of Longitudes in Paris, France. Because the Moon has stabilized Earth's rotation, we cannot know what Earth's early inclination was. They also found that Earth's inclination could have grown to 85° without the Moon's influence. So they conclude in the February 18, 1993 issue of *Nature* that the Moon has helped regulate our climate.

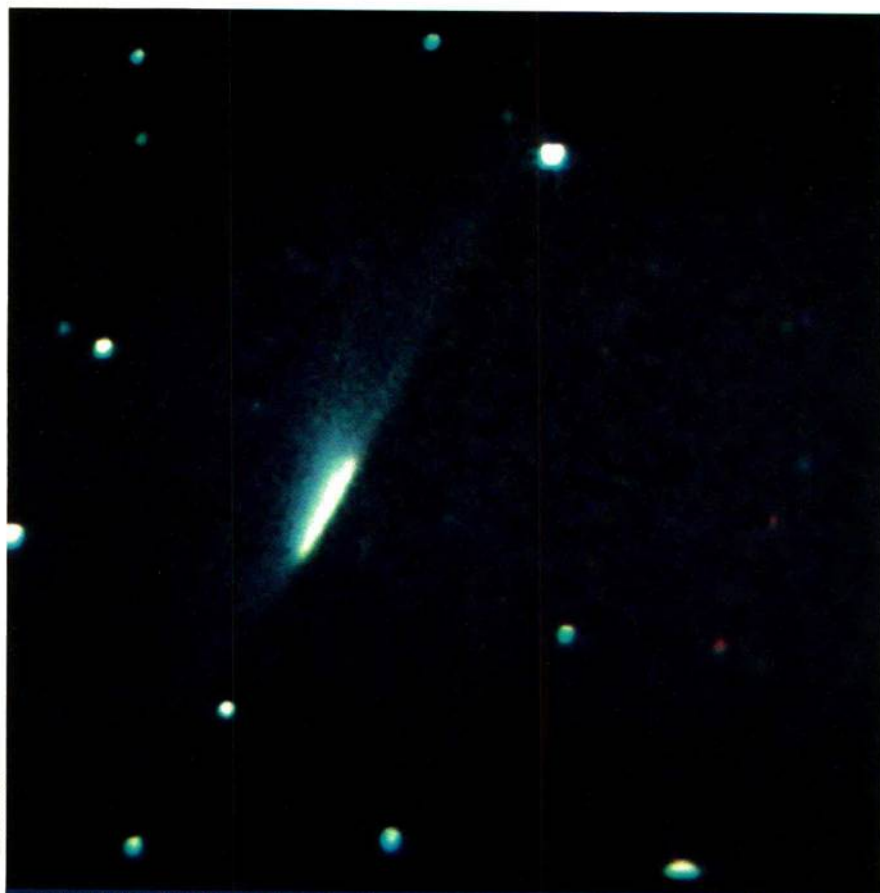
PROBING STELLAR BIRTHPLACES

Most stars may be born not in large stellar clusters but in small groups of only 10 to 50 stars. Until now, most astronomers thought stars formed either alone or in rich clusters containing hundreds or thousands of stars. But Karen Strom and Stephen Strom of the University of Massachusetts at Amherst and Michael Merrill of Kitt Peak National Observatory now think that idea may be wrong. They have discovered a number of small "stellar aggregates" comprised of extremely young stars, most of which appear to be surrounded by disks of material that may be producing planets.

Stars form deep within clouds of interstellar gas and dust. But it's hard to see the newly forming stars in these clouds because copious amounts of dust absorb the young stars' visible light. The clouds are far more transparent to longer-wavelength infrared radiation. The Stroms and Merrill used a sensitive new infrared detector array on the 1.3-meter telescope at Kitt Peak to map the interior of the dense interstellar cloud designated Lynds 1641, located 1,500 light-years away in the constellation Orion.

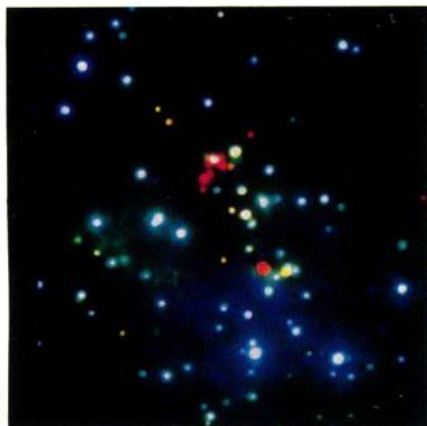
Their map reveals a prolific star-forming region that has been giving birth to stars nearly continuously for more than 10 million years. The youngest stars are among the youngest known, with ages of only a few hundred thousand years. And they congregate in intermediate-sized families that the researchers call aggregates, typically comprised of 10 to 50 stars in a volume about one light-year across.

These families won't last long — within a few million years their stars



COMET SHOEMAKER-LEVY (1993e) is one of the strangest comets observed. After its discovery on March 24, 1993, by Eugene and Carolyn Shoemaker and David H. Levy, astronomers recorded the comet as a cigar-shaped "train" of luminous material. Even more curiously, the comet contained seventeen nuclei appearing like "pearls on a string" according to one astronomer. Apparently the comet's close passage to Jupiter several years ago broke it apart. Shoemaker-Levy glowed at magnitude 13.8 at discovery and was expected to fade slowly over the following weeks.

Jack Newton



YOUNG STARS SHOW RED in this infrared image of a newborn stellar aggregate embedded in the interstellar cloud Lynds 1641. Separate images taken at 1.25, 1.65, and 2.2 microns were rendered blue, green, and red, respectively, to produce this image. The reddest objects are the youngest stars, still buried deep inside the cloud and surrounded by a disk of micron-sized dust particles.

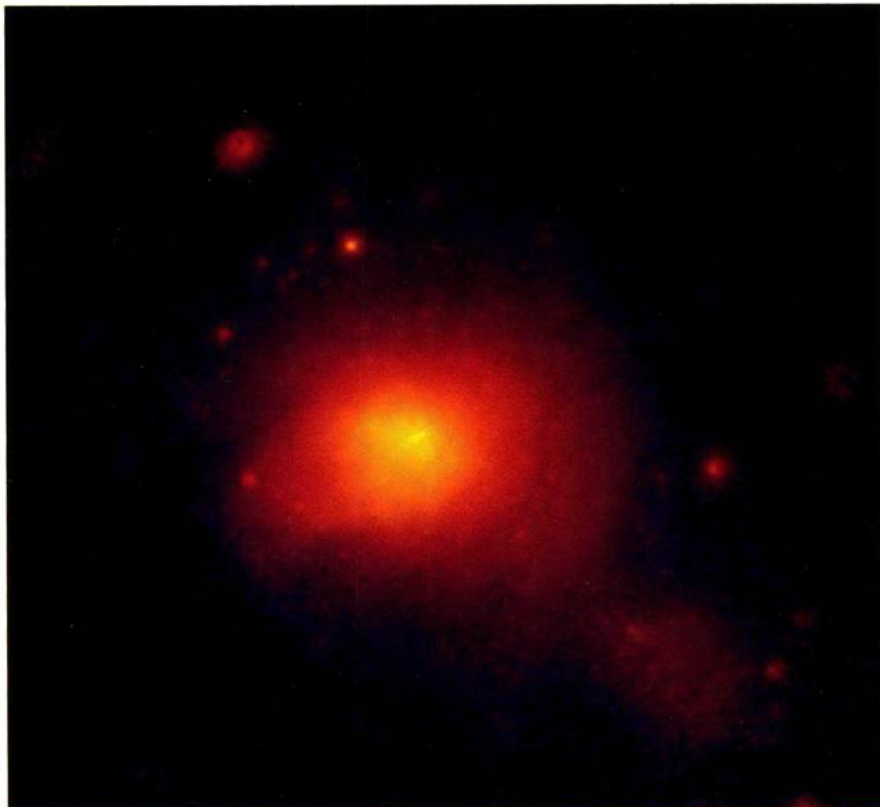
will have wandered some tens of light-years from their birthplaces. Thus the older stars in Lynds 1641 are distributed randomly throughout the cloud.

The infrared emission also shows the youngest stars in Lynds 1641 to be markedly different from the older stars. Most of the young stars radiate strongly in the infrared, just what you would expect from a disk of warm, micron-sized dust grains orbiting the star. The older stars emit only small amounts of infrared radiation, comparable to what the Sun emits.

The astronomers argue that the older stars emit a much smaller amount of infrared light because they are no longer orbited by swarms of small grains. Instead, the grains have coalesced into a much smaller number of larger bodies — planetesimals about the size of asteroids. The planetesimals may continue growing in size until one day these stars will possess planetary systems.

MIDWIFE GALAXIES

Companion galaxies may help trigger outbursts of star formation in dwarf galaxies. Normally dwarf galaxies are too small to experience the star formation bursts typical of large spiral galax-



THE COMA CLUSTER LOOKS CLUMPY in this new X-ray view of the rich cluster of galaxies. This highly detailed ROSAT image shows even more irregularities than previous observations hinted at and implies that the cluster is still forming as smaller groups merge into the main one (see "Is the Coma Cluster Still Forming" in the February 1993 *AstroNews*). The irregular structure at the cluster's center results from the presence of two supergiant galaxies that dominate this region. The bright region southwest of the main cluster (to the lower right) comes from a clump of galaxies surrounding the cluster's third brightest member, while the fainter region southeast of the center coincides with a clump of galaxies around the fifth brightest member of the cluster.

ies. But Christopher Taylor and Evan Skillman of the University of Minnesota and Elias Brinks of the National Radio Astronomy Observatory have found 28 dwarfs with active starbirth. They used the Very Large Array radio telescope outside Socorro, New Mexico.

Nineteen of the 28 galaxies have companion galaxies nearby that may have triggered the burst of star formation through gravitational interaction. The astronomers now seek to observe these companions in visible light. One of the companions that researchers already have observed in visible light shows no evidence for stars in it. Taylor and his colleagues remark that it and some of the other companions may be

"failed" galaxies — large clouds of gas unable to form stars themselves but capable of triggering star formation in nearby galaxies. Their observations may reveal new clues about how galaxies form and what sparks the formation of stars in galaxies.

NEW STAR DUE TO ARRIVE

In a scant million years, a new star will shine less than 4° southwest of the bright star Altair in the constellation Aquila. Shudong Zhou of the University of Texas and his coworkers found evidence that the gas and dust in the cloud named Barnard 335 (also called

Lynd's Dark Nebula 663) is collapsing into a star.

"We've believed for a long time that stars form from clouds in interstellar space when gravity causes the clouds to collapse," says Neal Evans, one of the astronomers in the research group. "However, we've had a hard time seeing the signature of a collapse." The scientists found the signature by measuring the gas speeds in the cloud using a 30-meter radio telescope at the Institut Radioastronomie Millimetrique near Granada, Spain, and a 10-meter radio telescope on Mauna Kea in Hawaii.

As they report in the February 10, 1993 issue of *The Astrophysical Journal*, the gas on the near side of the cloud moves away from Earth at 230 meters per second. The gas on the far side moves toward Earth at the same speed. The 0.1-light-year diameter of the cloud and the collapse speed imply that the cloud has been collapsing for about 150,000 years.

The star forming at the center (called a protostar) presently contains about four-tenths of the Sun's mass and has 6 times the Sun's diameter. The cloud contains about 12 solar masses, but astronomers are unsure how much of this mass will end up in the star. The cloud will continue to collapse for about a million years until the growing pressure and temperature inside the protostar start nuclear reactions, at which point the object becomes a star. If the new star is Sun-like, it will be visible to backyard astronomers only through telescopes because of its 750 light-year distance.

INFRARED SCOPE PLANNED FOR MOUNT EVANS

A bequest from the William Wombel estate will fund the University of Denver's new infrared observatory. The scope will sit on Mount Evans near the university's present scope, a 24-inch Cassegrain reflector. Located at 14,200 feet, the observatory is the world's highest. Because it sits above 40 percent of Earth's atmosphere and about 80 percent of infrared-absorbing water vapor, it is an excellent site for infrared astronomy. Robert Stencel, an astronomer at the university, says that one of the projects at the new observatory will search for planetary systems around other stars. The design team for the observatory is working with the U. S. Forest Service and environmentalists to minimize the impact of the new construction.



THE BRIGHTEST SUPERNOVA in six years was discovered on March 28, 1993, in the galaxy M81 in Ursa Major. F. Garcia of Lugo, Spain, found the 10th-magnitude supernova 45" west and 160" south of the galaxy's nucleus, some 30" northeast of a 14th-magnitude foreground star. Because M81 is so close — 10 million light-years away — the supernova was bright enough to observe with a 2-inch telescope. Canadian amateur Jack Newton made the CCD image at left on March 30, showing the supernova (arrow). The comparison image at top shows the galaxy's appearance last year.

Space News

IT'S LOW GAIN FOR GALILEO

They gave it their best. Engineers hammered away at it, but without results. Galileo's high-gain antenna remains stuck. During January, shortly after Galileo's final Earth encounter in late 1992, mission engineers pulsed the motor that unfurls the high-gain antenna hoping that the rapid banging would work the stuck antenna ribs loose. In January, the Jupiter-bound Galileo was as close to the Sun as it would get for the rest of the mission. Technicians hoped the added warmth would help free the antenna. But no luck.

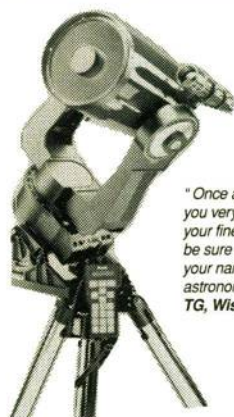
With the high-gain antenna out of commission and likely to remain so, mission scientists are now planning to use Galileo's low-gain antenna for the rest of the mission, including this year's flyby of the asteroid Ida in August. The low rate at which the spacecraft will be able to transmit precious bits of data back to

Earth will reduce the scientific return from Galileo. The biggest impact will be on studies of Jupiter's clouds. An early plan called for Galileo to take up to 50,000 images during its 23-month sojourn at Jupiter. Of these, 30,000 to 40,000 would have been devoted to tracking Jupiter's turbulent clouds on a regular schedule. Under the low-gain antenna mission, many of these cloud images will have to be sacrificed. Galileo will still return thousands of spectacular images of Jupiter, but not the quantity scientists would like for detailed time-lapse studies of Jovian weather systems. (The exact number of images we will get from Galileo will depend on the allotment of storage space on board the spacecraft to images versus data from other science experiments, something that won't be worked out for another year or two.)

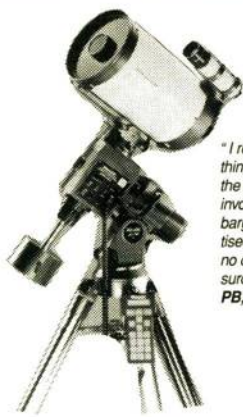
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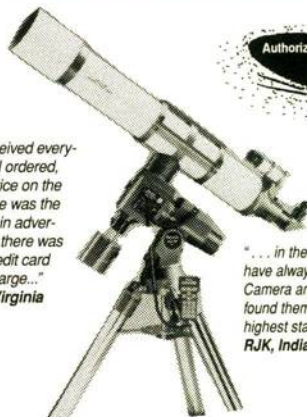
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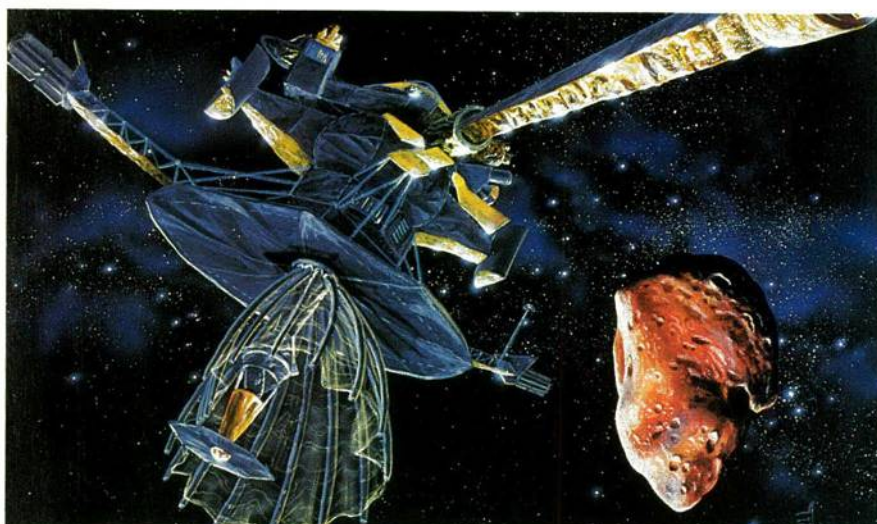
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LIKE A CRUMPLED UMBRELLA, Galileo's high-gain dish antenna remains partially unfurled, despite attempts to free the stuck antenna earlier this year. An artist's conception depicts Galileo flying past the asteroid Gaspra in October 1991 enroute to its final destination of Jupiter in December 1995.

The cutback in the cloud motion images isn't as bad as it sounds because scientists expect that the biggest discoveries about Jupiter's atmosphere will come from Galileo's entry probe, a part of the mission that remains unaffected by the switch to the low-gain antenna.

Ejected five months before Galileo gets to Jupiter, the entry probe will travel separately from the Galileo orbiter until encounter day. On December 7, 1995, the probe will slam into Jupiter's atmosphere at 170,000 kilometers per hour just before Galileo goes into orbit about the planet. During its hour-long descent, the probe will sample the atmosphere of Jupiter, relaying its findings to the orbiter. The probe's flight data will be stored on-board Galileo and played back a month or so later.

This critical tape load will also contain the mission's best images of Io, recorded during Galileo's closest approach to the volcanic moon for the entire mission, an encounter which occurs just hours before the probe's fiery flight.

In fact, most of Galileo's flight will now be handled as a "tape delay mission," similar to Magellan's recent exploration of Venus. As with Magellan, data will be recorded on board the craft and then played back once each orbit. In the case of Galileo, the mission calls for 11 long, looping orbits of Jupiter, each several months long. During most of each

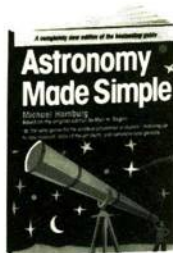
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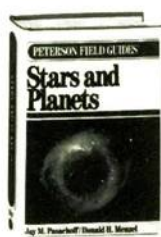
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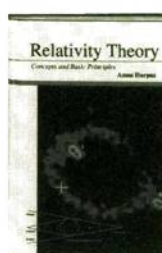
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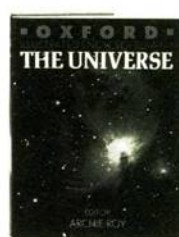
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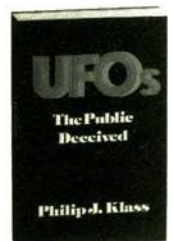
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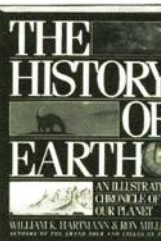
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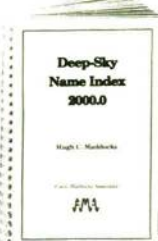
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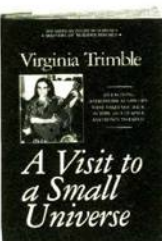
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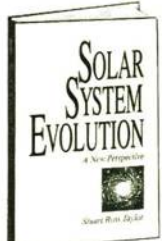
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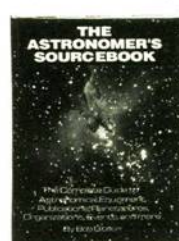
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orbit Galileo will be far from any of the giant planet's moons, particularly Jupiter's four large moons, the Galilean satellites of Io, Europa, Ganymede, and Callisto. But on ten of the orbits Galileo performs a brief but close encounter of one of these four moons, in some cases coming 20 to 1,000 times closer than either Voyager spacecraft ever did.

Images recorded during the few hours of each moon flyby will be played back up to several weeks later during a quiet time in each orbit — for example, when Galileo travels into Jupiter's shadow or when the craft is far from any target. Since imaging the moons is possible only for a few hours out of each orbit, the tape recorder can handle all the moon photos planned, including those resolving objects as small as a hundred meters across, ten times better than most Voyager images. Galileo should be able to map up to 50 percent of each of the four Galilean satellites at resolutions as good as one kilometer and up to 10 percent of their surfaces at resolutions better than a few hundred meters.

"The biggest payoff in understanding

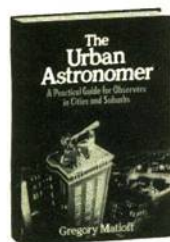
the surfaces of Jupiter's moons will come from the high-resolution images," says Torrance Johnson, Galileo's chief project scientist. "We are in the same position now with Jupiter's moons as we were with our own Moon before the space age, when all we had were pictures of the Moon taken through Earthbound telescopes. Voyager's images of the Galilean satellites are like telescopic shots of the Moon. By comparison, Galileo will take images of Jupiter's moons as good as Apollo's photos of the Moon taken from lunar orbit, with details sharp enough to tell us about the origins of many of the features we see."

Another major advance over Voyager will come from Galileo's NIMS experiment, the Near Infrared Mapping Spectrometer. There was nothing quite like it on Voyager. NIMS can take infrared images of planets and moons at many wavelengths that show the amount of heat coming from cloud and surface features. "There will still be lots of data from NIMS," points out Johnson. "In addition, the magnetosphere experiments are also in good shape." The particles and fields

experiments will send back a constant trickle of data through the low-gain antenna, enough to map the intense magnetic fields around Jupiter as Galileo makes its repeated passages through the radiation-filled magnetosphere.

So despite the antenna setback, mission scientists feel there is much to be excited about. By using clever data compression routines on board the spacecraft, upgrading the sensitivity of the receiving antennas here on the ground, and being very selective about what data to send back, "Galileo should be able to achieve at least 70 percent of its original science objectives," estimates Johnson. "However, we have just begun the job of redesigning the mission. It will take a year or two before the redesign is complete. But fortunately, Galileo contains all the computing power we need to handle the task."

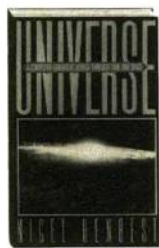
Adds Johnson confidently, "Once we get to Jupiter, it may be a few months before we get the first images and data back, but once the pipeline begins to flow we expect to have a constant stream of discoveries."



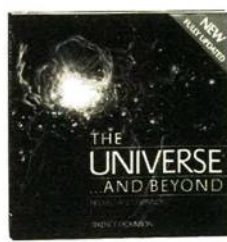
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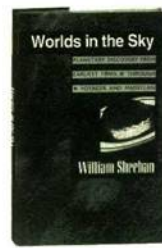
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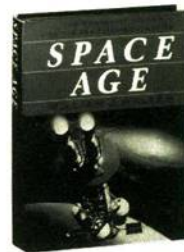
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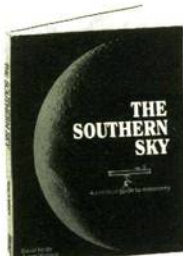
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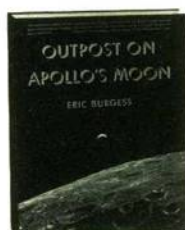
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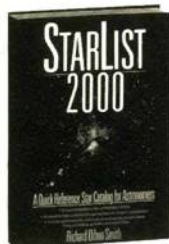
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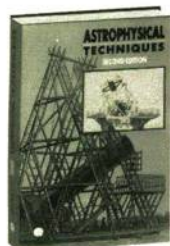
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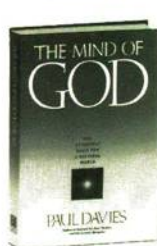
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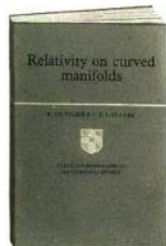
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Astronomy 7/93

THE UNIVERSE COMES TO CALIFORNIA



Courtesy Thomas L. Hunt

THE HISTORY OF SPACE ART will be one of many features at UNIVERSE 93 in San Diego this July. Visitors can also check out the latest in telescope hardware, computer software, and astronomy books.

What promises to be one of the year's biggest events in amateur astronomy is coming in July to San Diego. UNIVERSE 93, a national astronomy exposition and fair, will be two days packed with popular talks from well-known astronomers, "how-to" seminars on amateur astronomy, and exhibits of telescopes, accessories, and software from major manufacturers.

Sponsored by *ASTRONOMY* magazine and the Astronomical Society of the Pacific, UNIVERSE 93 is set for Saturday, July 10 and Sunday, July 11 in the Aztec Center at San Diego State University. The speaker line-up includes:

- Sallie Baliunas (Solar Cycles and Earth's Climate)
- Richard Berry (Image Processing for Amateurs)
- Elias Brinks (Dwarf Galaxies)
- Robert Burnham (Behind the Scenes at *ASTRONOMY*)
- Bruce Carney (The Age of the Universe)
- Mark Coco (The Green Flash)
- David Crawford (Light Pollution)
- Terence Dickinson (The Holy Grail of Amateur Astronomy)
- Doug Duncan (Hubble: Results and Repair)
- Alan Dyer (Choosing a Telescope)
- Stephen Edberg (Eclipse Chasing)
- Dave Eicher (The Next 20 Years in Astronomy)
- Timothy Ferris (Big Bang Theory)
- Alex Filippenko (Supernovae)
- Andrew Fraknoi (Debunking Astrology)
- Russ Genet (Robotic Telescopes)
- Jeff Goldstein (Earth Swallowed by the Sun)
- William Hartmann (Visions of the Solar System)
- Tom Hunt (History of Space Art)
- Hal Jandorf (Astronomy for Beginners)
- William Kaufmann (Black Holes)
- Ed Krupp (Mayan Astronomy)
- David Levy (Comet Hunting)
- Al Nagler (Highs and Lows of Magnification)
- Jack Newton (Color CCD Imaging)
- Don Osterbrock (Ritchey, Hale, and Big Telescopes)
- Yvonne Pendleton (The Kuiper Airborne Observatory)
- Marcus Price (Dark Matter)
- Sally Ride (Observing Earth from Space)
- Stephen Saunders (Magellan at Venus)
- Harding Smith (Active Galaxies and Quasars)
- Richard Talcott (Upcoming Celestial Events)
- Gerrit Verschuur (Spark That Bridged the Universe)

Conference organizers also expect exhibits and sales booths from dozens of manufacturers, many offering special show bargains on the latest telescopes, accessories, and other hobby merchandise. The program will also include a Saturday evening star party at the Reuben H. Fleet Science Center and an optional Monday tour of Palomar Observatory.

The two-day event will be open to walk-in attendance, but advanced ticket reservations are recommended. Admission for adults is \$15 for one day, \$25 for

a two-day pass, and for accredited students of any age \$8 for one day, \$15 for a two-day pass. Children under 12 are admitted free.

To receive a registration package for UNIVERSE 93, call the Astronomical Society of the Pacific at (415) 337-1100 or FAX (415) 337-5205. Or write Summer Expo, ASP, 390 Ashton Avenue, San Francisco, CA 94112.

CLUB HOSTS PRE-STELLAFANE STAR PARTY

Anyone who has spent a weekend at Stellafane in Vermont will agree that the annual telescope makers' convention is a great place to meet old friends, pick up bargains at the swap tables, and admire the fine examples of telescope-making handiwork. But the sheer number in attendance makes serious observing and astrophotography difficult.

With this in mind, from July 25 to August 2, 1992, twenty members of the Rockland Astronomy Club of Pearl River, New York (all seasoned Stellafane veterans), organized a week-long star party prior to Stellafane. For their dark-sky site, the group selected the Shady Pines Campground near the quiet Berkshire County town of Savoy, Massachusetts. The sixty-acre campground sits on a mountain plateau 2,200 feet above sea level and offers an unobstructed, smog-free horizon in all directions with the only light being two miles away.

Unlike most star parties around the country, the Rockland club did not charge any fees, nor did the program include any speakers or vendors. The event didn't even have a name. Daytime activities were left to the imagination of those in attendance. However, on Saturday, August 1, after a string of six clear nights, the star-party goers drove to the Stellafane site to attend the day's activities on Breezy Hill. By 10 a.m. everyone was shopping for bargains at Stellafane's famous swap tables.

The Rockland Astronomy Club is planning another pre-Stellafane camp-out and star party this year during the week before New Moon in July. To learn more, write to the Rockland Astronomy Club, c/o Don Urban, 73 Haring Street, Closter, NJ 07624. — *Don Urban*



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STELLAR ASTRONOMY

DANCE of the DOUBLE SUN



All illustrations by Michael Carroll

Two fast-spinning stars in Vulpecula
bear a remarkable resemblance to
the Sun — and hint that our star just
might have formed when two smaller
stars merged.

by Ken Crowell



TWIN SUNS HANG IN THE SKY of a minor
planet in the binary system ER Vulpecu-
lae. Both stars are nearly identical to the
Sun except they rotate almost 40 times
faster. This creates strong magnetic
fields that lead to huge starspots.





MTF

A good star is hard to find. We are here because our Earth lies at the right distance from a star that has both the right brightness and temperature for life. The Sun is hardly ordinary, for it outshines 95 percent of the stars in the Galaxy. Of the hundred nearest stars to the Sun, only one other matches it — a bright yellow main-sequence star with a spectral type of G2.

Stars like the Sun are worth studying because they give insight into the history and nature of our own star. For that reason, astronomers recently mounted a worldwide campaign to observe a 7th-magnitude star system named ER Vulpeculae, which lies 150 light-years away. ER Vulpeculae is doubly rare: It consists of two stars that are each just like the Sun.

"It's a great star," says Ed Guinan of Villanova University in Pennsylvania. "There are not many stars like it." Both members of ER Vulpeculae are yellow main-sequence stars of spectral type G having masses and diameters almost identical to those of the Sun. The warmer star has a spectral type of G1, the cooler star a spectral type of G2. In one significant way, however, the two stars differ from the Sun — each spins nearly 40 times faster, completing one rotation every 16.7 hours.

"ER Vul serves as a proxy for our own Sun," says Dave Bradstreet of Eastern College in Pennsylvania. "It gives us a unique laboratory in which to study what our Sun would be like if it were forced to rotate much faster than it does."

Today, the Sun spins slowly, completing one rotation in a month. But when it was young — when life was developing on Earth — it spun faster. Rapid rotation in a solar-type star produces huge starspots and flares, which is just what Guinan, Bradstreet, and their colleagues have observed on ER Vulpeculae. Such phenomena also occurred on the Sun when it was young, and the resulting radiation may have affected how life evolved on Earth. So ER Vulpeculae offers clues to the history of the Sun and Earth.

But the star system does more than that. ER Vulpeculae may also show us how contact binaries form. As the name suggests, contact binaries consist of two stars stuck together. Odd though they may seem, contact binaries are so common that the Galaxy has hundreds of millions of them.

Although the two stars of ER Vulpeculae are close together, they are not in contact. However, Guinan and Bradstreet believe the stars will eventually join to form a contact binary. Then the two stars will coalesce further and create a single star with about two times the Sun's mass. If this idea is right, many single stars, including our Sun, may have started their lives as close binaries.

"This is weird," says Guinan, "but it's not out of the question that the Sun could have formed from two smaller stars that had an initial period of one day or so and merged to become the Sun."

The Dance Begins

Astronomers discovered that ER Vulpeculae is double in 1946, before the star had received its present name. At that time, the star was known as HD 200391

TEN MILLION YEARS FROM NOW, the stars of ER Vulpeculae will have lost so much angular momentum that they will have spiraled into one another. Nearly ten percent of the stars in the Galaxy are contact binaries.

because it was number 200391 in a star catalog named for American astronomer Henry Draper.

Even today, no telescope shows the two stars separated from each other, because the stars lie too close together. One star's surface is only 1.5 million kilometers from its mate's, a distance equal to the Sun's diameter. Evidence that the star is binary comes instead from the spectrum.

In the 1940s, astronomers at David Dunlap Observatory in Canada were obtaining spectra of various stars to determine their velocity. HD 200391 was one of them. A star moving away from us has a spectrum shifted to longer wavelengths, or a redshift, whereas a star moving toward us has a spectrum shifted to shorter wavelengths, or a blueshift.

HD 200391's spectrum revealed both a redshifted and blue-shifted spectrum at the same time. The star was double: Its spectrum had lines from two different stars. As the stars revolved around each other, one star receded and had its spectrum redshifted, while the other star approached and had its spectrum blue-shifted. By measuring how these redshifts and blueshifts changed with time, Ruth Northcott found that the two stars revolved every 16.7 hours.

If HD 200391 were really two stars, the system's light might vary. The orbits of the two stars could lie along our line of sight, in which case the stars would periodically pass in front of each other and eclipse the more distant star's light. In 1955, Northcott's colleague, Gustav Bakos, discovered that the star's light did fluctuate, and HD 200391 was renamed as the variable star ER Vulpeculae.

Northcott and Bakos published their report in a half-page note in *The Astronomical Journal* in 1956. Then most astronomers forgot about it.

A Laboratory of Rapid Rotation

In recent years, however, astronomers have resurrected ER Vulpeculae because its two stars are so similar to the Sun. During the 1970s and 1980s, astronomers discovered that the activity that occurs on the Sun, such as spots and flares, also takes place on stars like the Sun. Such activity is especially pronounced on rapidly rotating stars like the two components of ER Vulpeculae.

On the Sun, spots and flares are powered by magnetic fields that pierce the Sun's surface. The Sun's outer layers are convective, which means that they transport energy by bubbling and boiling. Hot gas rises and carries heat upward and then sinks back down to pick up more heat. As it moves up and down, the gas drags magnetic field lines with it.

"These stars have almost identical properties to the Sun — masses, diameters, temperatures, and more — except they're spinning nearly 40 times faster."



MPCE
283

If the Sun's outer layers boil steadily, astronomers expect that the same holds true for both stars of ER Vulpeculae. But there's a difference, because the stars rotate faster than the Sun. Rotation amplifies a star's magnetic field and leads to greater starspot and flare activity.

"ER Vul is a laboratory for solar physics," says Guinan. "These are Suns, spun up. These stars have almost identical properties to the Sun — masses, radii, and all that — but they're spinning at nearly 40 times the Sun's speed."

The stars of ER Vulpeculae rotate so fast because they are tidally locked. No matter what rotation speeds the stars may have had originally, tides force one side of one star to face one side of the other, just as one side of the Moon always faces Earth. And because the two stars orbit each other every 16.7 hours, in order to face each other they also must rotate every 16.7 hours. Deep inside each star, this rapid rotation produces a powerful magnetic field that is carried up to the surface by the boiling gas. Once the fields reach the surface, they erupt in plentiful spots and flares.

ER Vulpeculae's spots are so large and numerous that they show up in its light curve, a plot of the star's brightness with time. Because the two stars are nearly identical, the two eclipses should be, too: An eclipse of the G1 star by the G2 star should look like an eclipse of the G2 star by the G1 star.

But that's not the case. "The light curves are not clean," says Bradstreet. "They're very asymmetric. And they change from year to year. Different parts of the light curve have different asymmetries from year to year — and even from month to month." The asymmetry results because one star is more spotted than the other. When the more spotted star, which is darker, eclipses the less spotted star, the system's light drops more than when the opposite occurs. But the spots move around on the stars, so the light curve never stays the same for long. Furthermore, the system's light can jump in just a few minutes or hours when huge flares erupt.

In 1991, Guinan and Bradstreet led an international campaign to follow ER Vulpeculae for nearly two days, during which time the stars completed more than two orbits. Cafer İbanoğlu in Turkey, Dave Steelman, Troy Thrash, and Chris Ready at Villanova University in Pennsylvania, Paul Etzel in California, and Il-Seong Nha in Korea observed the star, providing around-the-world coverage so that the star was always visible from at least one observatory.

Meanwhile, Guinan and Bradstreet tracked ER Vulpeculae with the International Ultraviolet Explorer (IUE) satellite. Ultraviolet radiation pours from the higher regions of a star's atmosphere where gases have been heated by strong magnetic fields. The IUE observations showed levels of ultraviolet emissions from ER Vulpeculae that were up to hundreds of times more intense than those produced by the Sun.

Guinan and Bradstreet then modeled all of the data. They found that both stars have large starspots, which cover up to 30 percent of the stars' surfaces.

By solar standards, these spots are huge — if the Sun

had a spot that big, you could easily see it with your naked eye. But the Sun itself may have once been like the heavily spotted stars of ER Vulpeculae. Shortly after it formed, the Sun spun faster than it does now, so it must have had a stronger magnetic field, more sunspots, and more flares. Such activity could have affected — for better or for worse — the development of life on Earth.

"One way of looking at ER Vul is that these stars are similar to what the Sun may have been like when it first formed," says Guinan. "The Sun's rotation period was then around two days, so these stars are spinning even faster than that."

Like the Sun, ER Vulpeculae may have planets. If so, one of these planets may lie at the right distance from the pair (about the distance of Mars from the Sun) to have the right temperature for liquid water, an essential ingredient for life. Furthermore, ER Vulpeculae is 2 to 4 billion years old, old enough that some type of life may have developed on one of its planets.

"It would be an interesting system to have as your Sun," says Bradstreet. But any life there would face challenges. "Although these are solarlike stars," he says, "because of their rapid spin, that's going to increase magnetic flaring activity and ultraviolet emission many-fold over our Sun. That's not too conducive for any kind of life. A planet would have to have a really strong ozone layer to support our kind of life."

Though the Sun once spun fast, it slowed down because it lost angular momentum, creating a solar system more hospitable for life. Angular momentum is a product of mass distribution and spin rate. A spinning star has angular momentum, as do two stars revolving around each other in a binary system. The Sun loses angular momentum because its magnetic field lines stretch into the interstellar medium. As the Sun spins, these magnetic field lines spin with it. The field lines "scrape" against the interstellar medium, which causes the Sun to spin more slowly and lose angular momentum.

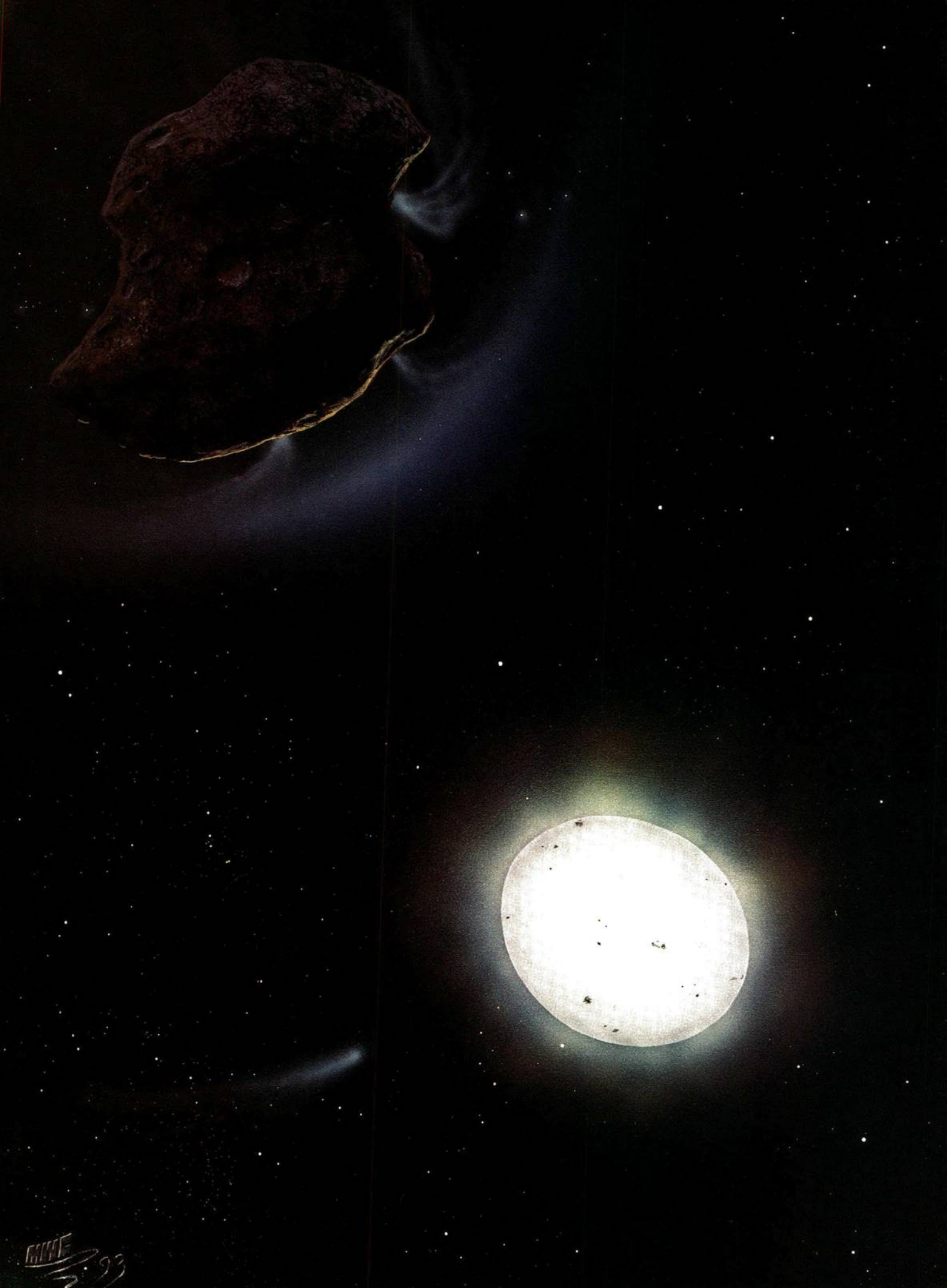
And Then There Was One

The stars of ER Vulpeculae are also losing angular momentum. Yet in their case, the outcome will be far more dramatic: The two stars will slowly pull closer to one another, eventually forming a contact binary when their atmospheres meld together, and ultimately merge into a single star.

Like the Sun, ER Vulpeculae's stars have magnetic field lines that stretch into space, rotating as the stars do. And as these field lines scrape against the interstellar medium, the stars also lose angular momentum. If either star were single, like the Sun, it would lose

The two stars will spiral closer, forming a contact binary when their atmospheres meld, and ultimately merge into a single star.

LOOKING LIKE A GLOWING PEANUT, the contact binary continues to shrink as the centers of the formerly individual stars draw closer together.



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A HUNDRED MILLION YEARS IN THE FUTURE, the two stars of ER Vulpeculae will have merged into a single star. It will appear as an ordinary white star — much like the bright star Sirius — with a mass just over two solar masses.

angular momentum simply by spinning more slowly and end up like the Sun.

But the stars of ER Vulpeculae cannot spin more slowly, because they are tidally locked and must spin as fast as they revolve. Something has to give, however. Because ER Vulpeculae is a binary, the system has an additional reservoir of angular momentum: the stars' orbital motion around each other. So the stars lose angular momentum not by spinning more slowly but by coming closer together. As the stars come closer together, they revolve around each other faster and the orbital period decreases, and the tides force the stars to spin faster.

"There's some evidence of a slight decrease in ER Vul's period," says Guinan. "We might actually be seeing angular momentum loss." He admits, though, that the evidence is not conclusive and that more data are necessary.

But the fate of ER Vulpeculae, think Guinan and Bradstreet, is clear: a contact binary. Says Bradstreet, "As the stars lose angular momentum and continue to spiral in closer and closer to each other, eventually they'll come into contact." Bradstreet estimates that ER Vulpeculae will become a contact binary in only about ten million years.

Contact binaries are important to understand because they are so numerous. Roughly one in every thousand stars is a contact binary, so our Galaxy is full of these exotic objects. The prototype contact binary is W Ursae Majoris; the nearest contact binary is 44 Bootis B, which lies a mere 38 light-years away.

"If this is the process by which contact binaries are made," says Bradstreet, "then contact binaries are a common graveyard of many binary stars. Perhaps almost all close binaries eventually come into contact."

Evidence that contact binaries are made rather than born comes from their ages: Contact binaries tend to be middle-aged or old. For example, the old open star cluster NGC 188 in Cepheus, which is 6 to 10 billion years old, contains at least 7 contact binaries, whereas younger star clusters have few or none. In addition, Guinan and Bradstreet have found that instead of traveling in circular orbits around the Galaxy, contact binaries tend to follow fairly elliptical orbits, which is a sign of old age and suggests that most contact binaries are 5 to 10 billion years old.

But these systems cannot have been contact binaries all their lives, because the contact stage is transitory. No contact system can last longer than a billion years or so. As they orbit each other, the two stars in a contact binary continue to lose angular momentum until they coalesce into a single star. Such coalesced stars have been identified; the prototype is a yellow star named FK Comae Berenices. (See "When Stars Coalesce" by Ken Croswell, May 1985.)

If the contact stage is short-lived, then the old contact binaries in NGC 188 and elsewhere could not have been born that way. Instead, they must have started life as short-period binaries like ER Vulpeculae.

"The contact stage seems like a stage that would be

short," says Guinan, "because you have a lot of fireworks going on. It could be as short as 100 million years or less. If that's true, then you have all these stars merging to become single stars."

When the two stars of ER Vulpeculae merge, they will form a single FK Comae-type star. At the moment, the G1 star in ER Vulpeculae has 1.10 solar masses and the G2 star has 1.05 suns. So once the two stars in ER Vulpeculae finally merge, they will form a single star with a mass of 2.15 solar masses. ER Vulpeculae will then be a white star of spectral type A, similar to Sirius.

"The strange thing about it," says Guinan, "is that if this contact stage doesn't last long, then there are major problems. Contact binaries are common, but if they don't last long, then you have to explain where all the contact binaries that once existed have gone. How many single stars were once contact binaries: Is it a large fraction? And it can be large. It can be one percent. It can even be that ten percent of the [single] stars [in the Galaxy] could be former binary stars."

No Sun of Mine

"If these mergers are so common," says Guinan, "then maybe the Sun went through one of these episodes." ER Vulpeculae has raised the slim possibility that our own Sun was once a close binary.

If the Sun began its life as a double star, however, it was not identical to ER Vulpeculae. The two stars of ER Vulpeculae together add up to 2.15 solar masses, whereas the two stars that conceivably created the Sun must have added up to only one solar mass. One possibility is that one star was an orange star with a mass of 0.7 suns and the other was a red dwarf with a mass of 0.3 suns. Over time the two stars came together and formed a contact binary. Then the two components of the contact binary merged to become a single yellow G star with a mass of one sun.

"It sounds like science fiction," says Bradstreet, "but our Sun could have been a contact binary four or five billion years ago and we might never know it." The only witnesses to the event would have been astronomers who lived long ago, elsewhere in the Galaxy, who puzzled over the behavior of the peculiar binary star that was to become our Sun — just as we now puzzle over ER Vulpeculae.

Imagine what they could tell us. □

"It sounds like science fiction, but our Sun could have been a contact binary four to five billion years ago."

Ken Croswell is an astronomer in Berkeley, California, and frequently writes for ASTRONOMY, New Scientist, Star Date, and other publications. His last article for ASTRONOMY was "The Titan/Triton Connection" in the April 1993 issue.

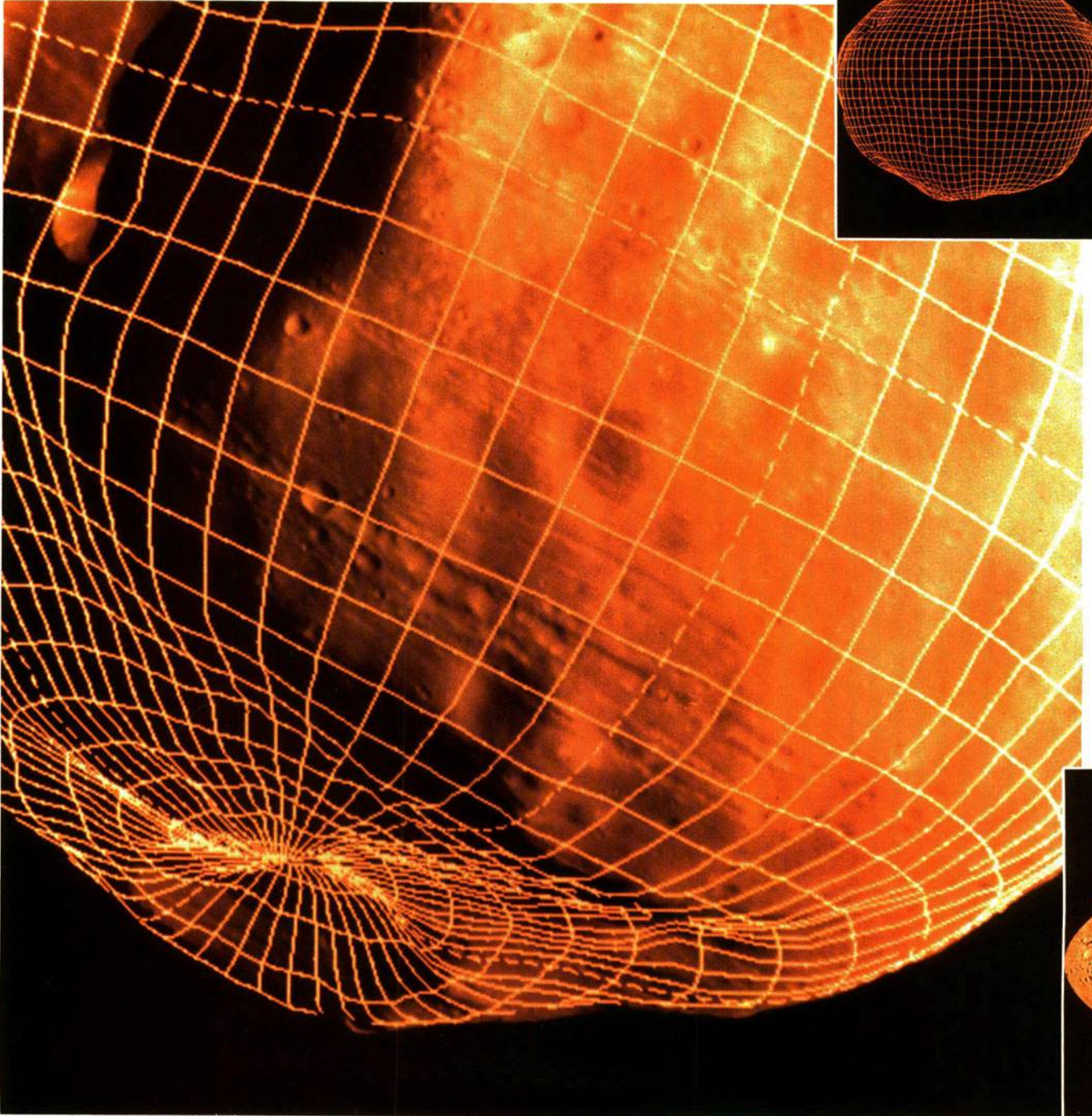
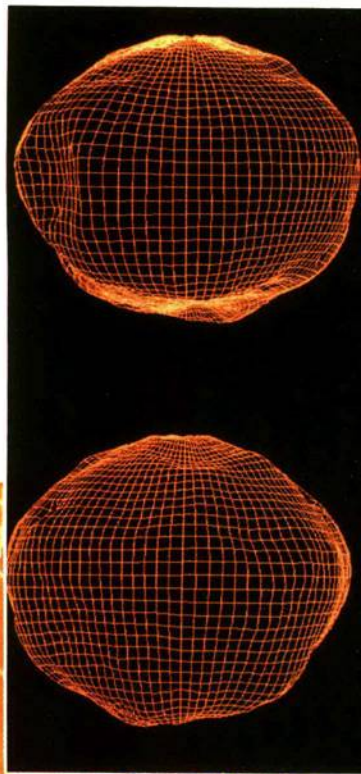
PLANETARY MAPPING

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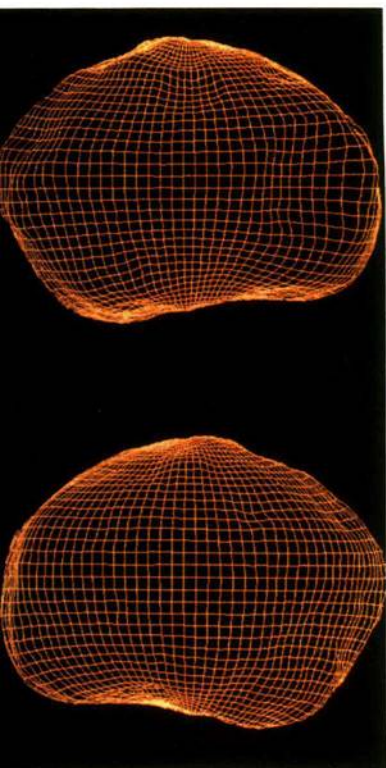
or How to Map a Potato

North and south, east and west, aren't always obvious on an irregular world like Phobos.

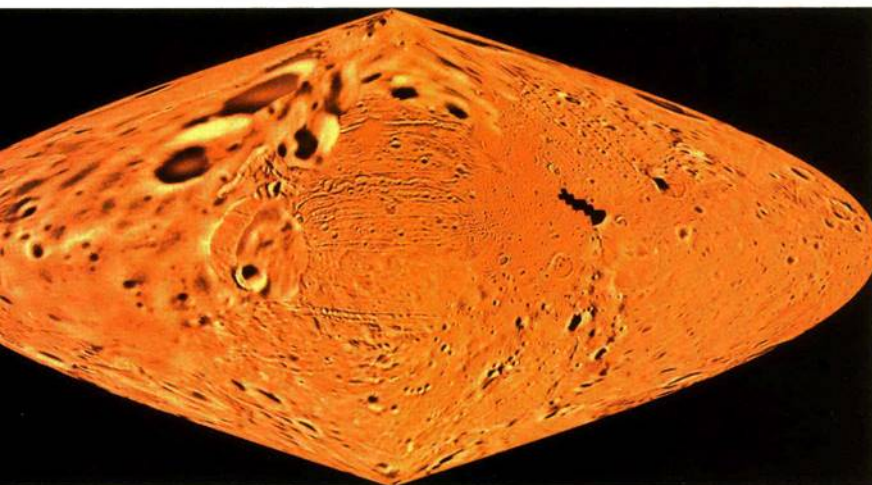
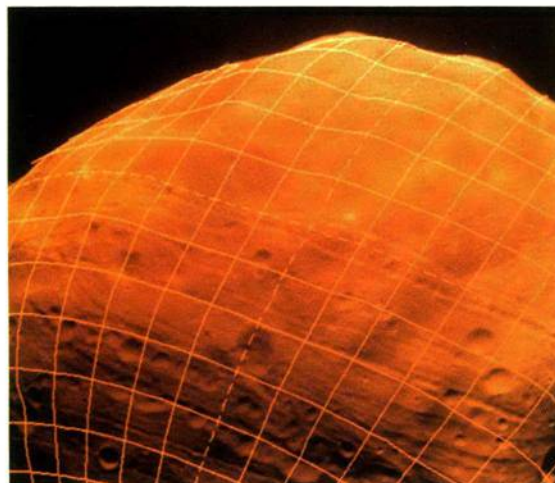
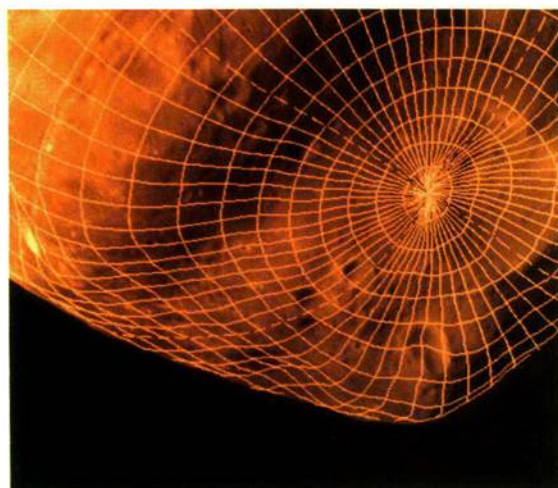
by Damon Simonelli



NASA/JPL, Peter Thomas, Cornell University



DENTED AND MISSHAPEN, the Martian moon Phobos poses a challenge for anyone mapping its surface. A new computer program named Spud lets planetary scientists create mathematical models of irregular objects using spacecraft images. With the program scientists bend and deform an idealized egg shape to create a model (above) that matches images of the object's surface. The shape model then helps scientists create global photo-mosaic maps of the object (such as below) and investigate its surface properties.



Your geographic location (latitude and longitude) is pretty easy to determine when you live on a round body like Earth. But on a misshapen "potato" like Mars' moon Phobos, it's entirely different.

To map such irregular objects, my Cornell colleagues Peter Thomas and Brian Carcich and I have developed a computer program named Spud. Behind the nickname is a serious purpose: Scientists need detailed mathematical models of irregular bodies that give insights they can't get any other way.

For example, since Phobos is irregular, its gravity field is also. Thus anything flying over its surface will not follow a smooth, elliptical trajectory, but will move in and out as it passes over different regions. The strength of the surface gravity isn't the only thing that changes — its direction changes too. Scientists need to understand which way is up at any point on the surface because this controls where the debris blasted out of an impact crater will land and in which direction loose soil and rubble will slide.

Shape also helps scientists decipher the brightness variations of the surface. As seen by reflected sunlight, surface brightness depends on viewing angle, texture (is it rough, smooth, porous, dense?) and how far above the local horizon the Sun is. Viewing angle is easy to work out, but the local Sun elevation isn't if the horizon is part of a potato!

In practice, wrapping a geographic network onto a body like Phobos requires close-up images from many viewpoints. Using Spud, we start with a rough approximation of the object's shape, such as an egg, and then adjust the shape, denting and distorting it to match the shape required by the images. The result is a computer model in which every surface point has a latitude, a longitude, and a distance from the body's center. This model becomes the frame on which scientists piece together the images into a global map.

We tested Spud on Phobos because it's the most thoroughly imaged irregular object. Spud is also helping us model Gaspra, the asteroid imaged by Galileo. This poses a bit of a challenge because Galileo photographed less of it and at lower resolution than Viking did Phobos. Galileo's next asteroid target is Ida, which the craft will encounter on August 28. We suspect from telescopic observations that Ida has an irregular shape, but how it will look close up is anyone's guess. Stay tuned! □

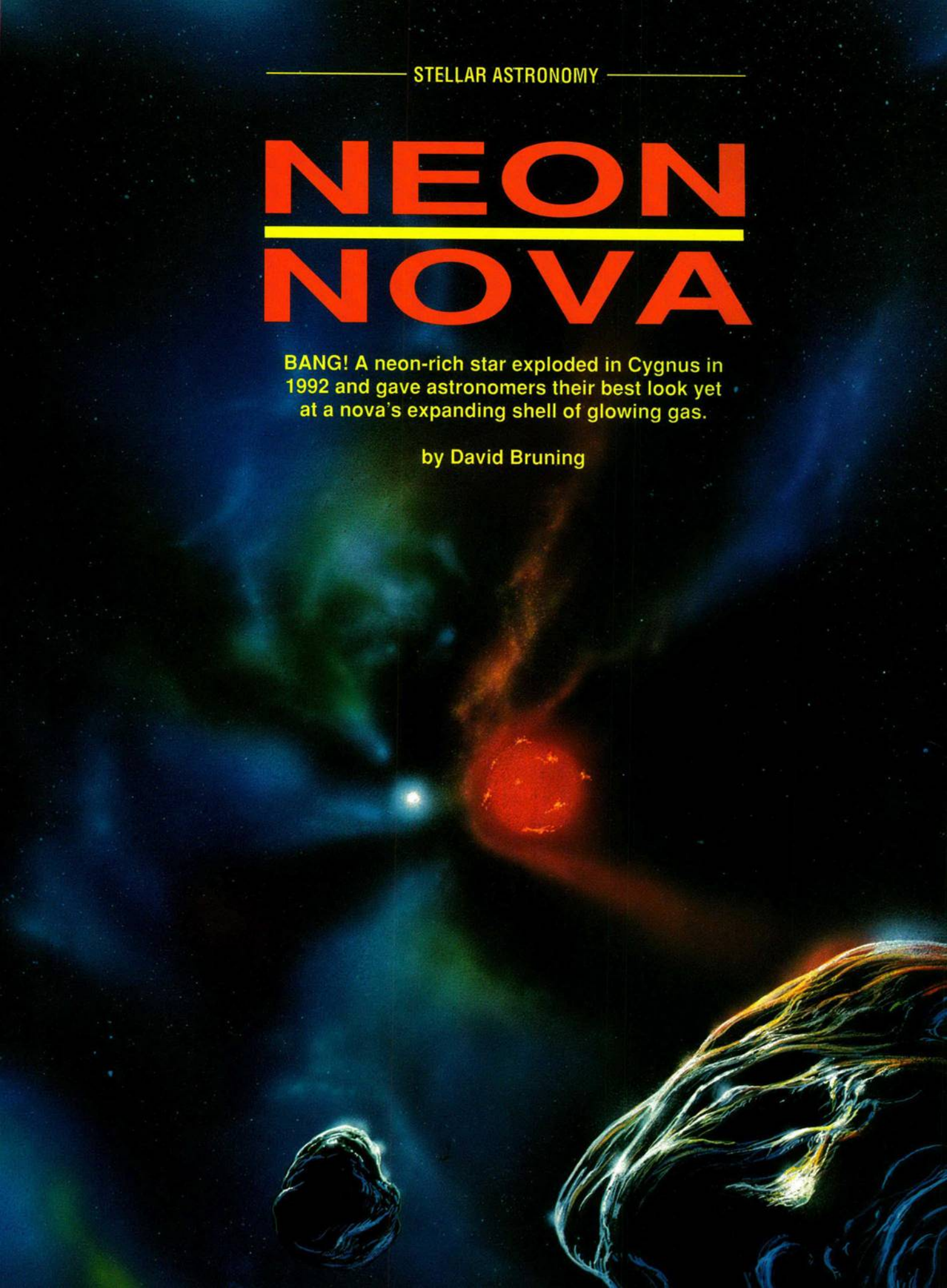
Damon Simonelli is a research associate at Cornell University working on the Galileo mission to Jupiter.

STELLAR ASTRONOMY

NEON NOVA

BANG! A neon-rich star exploded in Cygnus in 1992 and gave astronomers their best look yet at a nova's expanding shell of glowing gas.

by David Bruning



February 18, 1992, is a date Peter Collins will never forget. That evening as he watched the constellation Cygnus set in the northwest, the Boulder, Colorado amateur astronomer noticed an unexpected star — a nova — about 6° north of Deneb, the constellation's brightest star. Collins knew that novae form in binary systems containing a white dwarf. The white dwarf explodes after gas from the companion star streams onto its surface.

What made Nova Cygni 1992 interesting was that it was the brightest nova in 17 years, nearly equaling the outburst of Nova Cygni 1975. Besides its uncommon brightness, Nova Cygni 1992 presented another rarity for observers — the star showed strong neon lines in its spectrum, indicating that it was a neon nova. Being the closest neon nova ever observed, this one gave astronomers an unprecedented view of how these stars explode.

This new collection of data will help astronomers learn more about how stars evolve in binary star systems. It will also help them predict how much these stars brighten, which is important for researchers using nova brightness as an indicator of the distances to faraway galaxies. And knowing the chemical makeup of the gaseous shell ejected by these stars will help astronomers decipher how hydrogen and helium gas in galaxies is enriched with heavier elements.

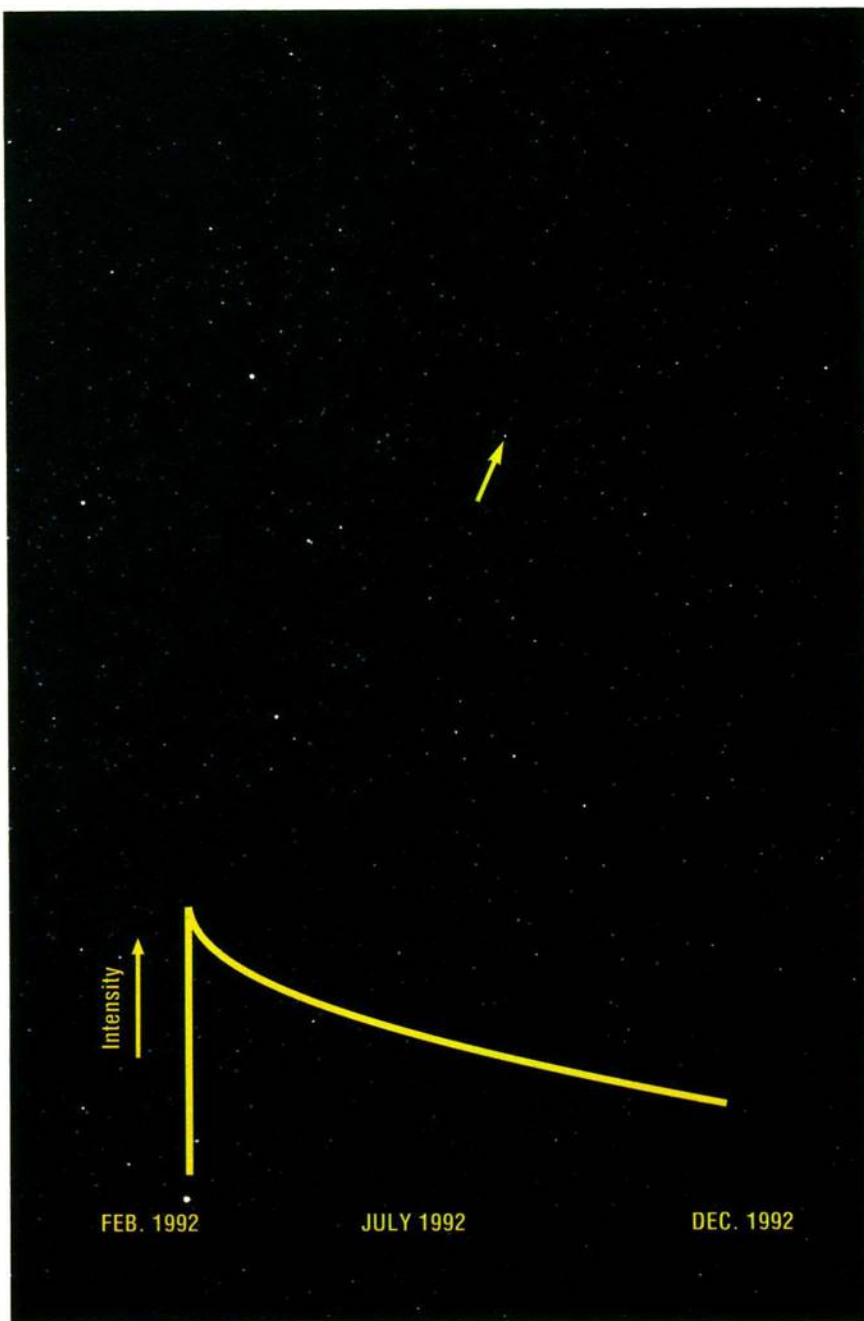
All this began with Collins' discovery.

Finding Its Size and Distance

Collins caught the star just after it had exploded. He estimated the nova appeared at magnitude 6.8. Four days later, it shone at its brightest, magnitude 4.2. The explosion caused the star to brighten by up to 100,000 times (12.5 magnitudes), so the star probably appeared at only 16th magnitude before it went nova. Just one week after discovery, the star had dropped down to 6th magnitude. And this summer it has faded to under 12th magnitude.

While dedicated amateurs carefully measured the nova's brightness (see the American Association of Variable Star Observers' brightness curve above), professional astronomers turned their space- and ground-based instruments to the star. They viewed the star at all wavelengths from gamma rays to radio waves. The Hubble Space Telescope (HST), Roentgen X-ray Satellite (ROSAT), International Ultraviolet Explorer (IUE), Kuiper Airborne Observatory, Compton Gamma Ray Observatory (GRO), and even Voyager 2 saw it.

On the night of February 28, Andreas Quirrenbach of the Universities Space Research Association and his associates measured the diameter of the expanding shell. Never before had observers been able to measure a nova's diameter so soon after outburst. (Nova Cygni 1992's shell will take until the fall of 1994 to grow to one arcsecond across.) But the astronomers made this measurement with a unique new instrument — the Mark III optical interferometer located on Mount

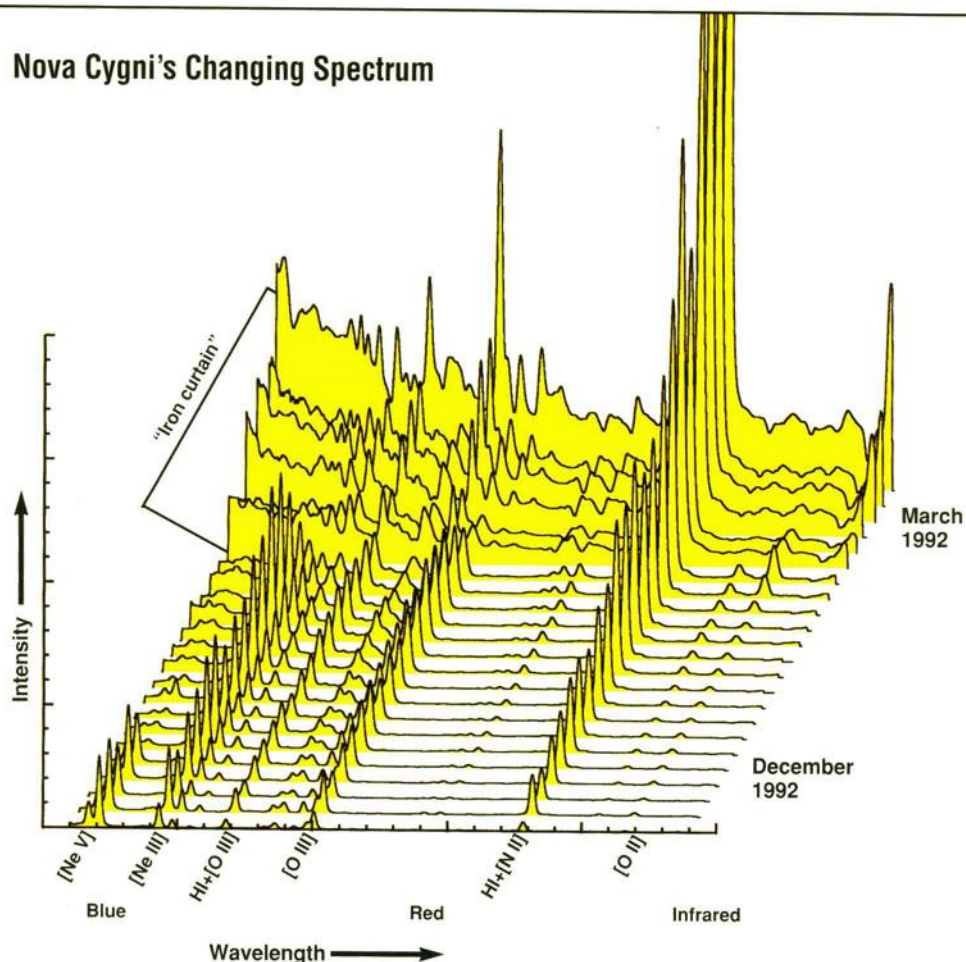


NOVA CYGNI 1992 BLAZED as bright as magnitude 4.2, about 6 degrees north of Deneb. The light curve shows how the nova changed in brightness from February to December 1992.

Wilson, just north of Pasadena, California. This instrument combined the light from two small telescopes to mimic the resolution of a larger telescope. To view Nova Cygni, researchers separated the 2-inch-diameter telescopes by 66 feet to match the resolving power of a 66-foot (20-meter) telescope. Their observations showed the expanding shell was only 0.005 arcsecond, or a millionth of a degree, across.

From spectroscopic measurements made elsewhere, astronomers estimate that the shell traveled at a speed up to 1,900 kilometers per second shortly after the outburst. Coupled with the time of outburst and the shell's expansion speed, Nicholas Elias of the U. S. Naval Observatory says, "The angular diameter allows us to estimate the Earth-nova distance using only simple

Nova Cygni's Changing Spectrum



BRIGHT NEON LINES SHOW that Nova Cygni resulted from the explosion of a neon-rich white dwarf. The fall of the continuous radiation ("iron curtain") marks the end of the thick shell phase and the beginning of the nebular phase.

geometry. The distance to the nova must be between 7,300 and 9,500 light-years."

The nova's distance and the shell's expansion speed weren't the only things astronomers could learn from the star's spectrum. Spectral lines revealed the shape of the nova and chemical composition of the shell's gas.

Round and Knotty

A radio map (opposite) made last December by Robert Hjellming at the Very Large Array outside Socorro, New Mexico, showed the basically symmetric shape of the nova's shell. The map also enabled Hjellming to estimate that the shell contains about 0.03 percent of the Sun's mass. But spectra showed this ring of material contained many knots and blobs of gas. This indicated that the explosion was clumpy and non-spherical. Previously, astronomers had suspected that some novae ejected material asymmetrically. But for Nova Cygni 1992, observations from HST, IUE, and ground-based telescopes clearly showed the nova ejected its shell in several pieces.

Nowhere was the asymmetric shape more apparent than in measurements of polarized light coming from the shell. Light acts like a wave with individual light waves moving up and down in a plane. A star such as the Sun emits light waves that are oriented in all direc-

tions, but a gaseous shell can orient light waves preferentially in one direction. Special instruments called polarimeters can measure the orientation, or polarization, of the shell's light. In the case of Nova Cygni 1992, polarization measurements made at the University of Wisconsin's Pine Bluff Observatory by Karen Bjorkman and her group indicated that the shell was about 10 percent flatter than a sphere.

HST observations by Steven Shore of the Computer Sciences Corporation and his collaborators showed the shell was hollow. Its thickness in September was about 30 percent of the shell's radius. The observations also revealed that the expansion wasn't smoothing out the shell. Instead the knots of high-density gas formed during the explosion didn't mix with low-density, slow-moving clumps of material. According to Shore, this lack of mixing helped observers map the shell's structure, creating something like a CAT-scan of the nova.

For the first time, observers could watch the nova's spectrum change as the shell's structure evolved. (See the series of spectra at left taken with the 36-inch telescope at Pine Bluff Observatory.) Early spectra showed strong emission of light at all wavelengths (astronomers call this continuum), but particularly at blue wavelengths. It resulted from a process nova experts have dubbed the "iron curtain." Metal atoms, primarily those of iron, strongly absorbed ultraviolet light emitted by the nova. These atoms re-emitted the light as the continuous part of the visible spectrum.

As the shell thinned, the iron curtain fell. The gas was no longer thick enough to absorb the ultraviolet light and the re-emission in the visible decreased greatly. The spectrum then resembled that of a gaseous nebula with light emitted only at specific wavelengths.

Glowing Like a Nebula

The strong hydrogen lines that dominated the visible spectrum shortly after the outburst decreased in brightness as the iron curtain dwindled. As the nova moved into the nebular phase, atoms in the expanding gas had some of their electrons stripped away by the strong ultraviolet radiation coming from the star. Previously, the iron atoms had absorbed this ionizing radiation, but the gas in the nebular phase wasn't thick enough.

The thinness of the shell permitted the emission of lines of ionized nitrogen, [N II], and oxygen, [O II] and [O III]. The Roman numerals indicate that the atoms had one (II) or two (III) electrons stripped away. The square brackets indicate that these lines occur only under special conditions, typically in rarefied gases such as those found in planetary nebulae.

As the iron curtain died away and the nebular shell started glowing, another set of lines appeared in the spectrum. These were lines emitted by neon, largely [Ne III] and [Ne V], and their strength indicated the shell contained four times more neon than normally found in stars. This showed Nova Cygni 1992 wasn't an ordinary nova. It was a somewhat rare oxygen-neon-magnesium-type nova, or neon nova for short. This clue told astronomers about the nature of the star that exploded.

Making a Nova

Photometric monitoring of Nova Cygni 1992 in September by Mary Taylor and her colleagues at the University of Wisconsin showed the system is possibly of the type characterized by the binary star AM Herculis. These binary systems contain a white dwarf and a red dwarf companion.

The white dwarf was originally the more massive star. But it used up its nuclear fuel quickly and evolved into a red giant before ending its life as a white dwarf.

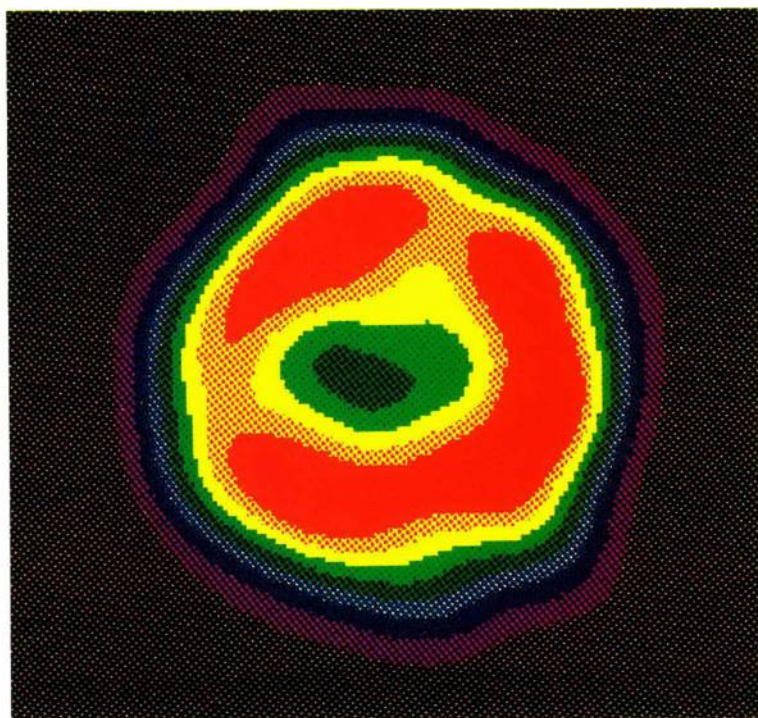
The two stars are so close together that the gravity of the white dwarf pulled material away from the red dwarf's atmosphere. This gas collected around the white dwarf in a disk. Eventually the gas spiraled into the star's surface. By the time it hit the surface, the gas became very hot. Nuclear reactions started, heating the gas further and starting a runaway process that drove the temperature up to billions of degrees.

This extremely hot region exploded, driving the surrounding gas outward at speeds up to several thousand kilometers per second. The white dwarf and red dwarf both survived because only a small amount of mass exploded. But the intense heat of the expanding fireball shielded the stars from view until the gas thinned enough to become transparent or nebula-like.

Neon lines in the expanding shell's spectrum indicated that the white dwarf is more massive than average. As it evolves, a low-mass star converts its core hydrogen into helium, and during the red giant phase convert this helium into carbon and oxygen. A massive star takes this nuclear transformation even further, generating neon and magnesium from lighter elements.

The explosion blew some of this neon and magnesium off the star's surface. And radioactive sodium that formed from neon during the explosion joined the ejecta. When radioactive sodium decays back into neon, it emits gamma rays. These gamma rays can travel only a short distance before material in the shell absorbs their energy and re-emits it in the form of X rays. GRO and ROSAT will search for this emission to see if the models that predict how much sodium formed are correct. The amount seen in Nova Cygni 1992 may help pin down the white dwarf's mass.

Another mystery that may be solved by observations of Nova Cygni 1992 is that of the amount of radioactive aluminum seen in the solar system. Meteorites contain far more radioactive aluminum than can be easily explained by current theories. Sumner Starrfield of Arizona State University suggests that this material formed from magnesium in neon novae. "It seems possible that such a nova exploded near the forming solar system," he says. "Thus the analyses of Nova Cygni 1992 may relate to the formation of the solar system."



Robert Hjellming

THE EXPANDING SHELL APPEARS almost perfectly round in this radio map. But other observations show that the shell has knots and lumps that expand at vastly different speeds.

Solving a Mystery

Although the nebular phase revealed the identity of the star that exploded, it isn't the last phase in a nova's evolution. Two more phases follow the nebular stage: the coronal phase, during which the shell's spectrum looks like the hot outer atmosphere (corona) of a star, and the dust formation phase.

The coronal phase began in September 1992, when Harriet Dinerstein and her coworkers at the University of Texas saw the signatures of highly ionized species of aluminum, silicon, and calcium. Peter Garnavich of the Dominion Astrophysical Observatory also saw ionized iron lines in the optical spectrum.

Observations of these lines answered a long-standing question. Astronomers were unsure whether shock waves permeating the shell or strong radiation from the star created the lines. Infrared observations of Nova Cygni 1992 by Robert Gehrz of the University of Minnesota and his colleagues showed that the radiation from the newly exposed white dwarf ionized material in the shell, which then emitted the coronal lines seen.

By December, infrared astronomers had not yet seen the dust formation phase. They are on the lookout though, because they suspect neon novae create dust made of silicon rather than carbon, which other novae produce.

The two questions astronomers want to answer about Nova Cygni 1992 concern the presence of silicon dust and the amount of radioactive sodium and aluminum it produced. The rest of the observations have been a great success. Astronomers watched the shell change from the fireball to the nebular phase, learning what type of star exploded and how much gas the nova ejected. The coronal phase showed that radiation from the hot white dwarf rather than shock waves controlled the emission of the shell. Nova Cygni was not only the brightest nova in 17 years but also one of the most revealing, as it shared its secrets with astronomers. □

COSMIC TUG OF WAR



Our Milky Way Galaxy and many others are streaming toward a region of the universe called the Great Attractor. This large mass is just one of many that play a game of cosmic tug of war with our Galaxy.

by David Burstein and Peter L. Manly

Our Galaxy and the Andromeda Galaxy dominate the Local Group of galaxies. The galaxies move within the Group at 270 km/s.

Cosmologists once thought the universe was expanding smoothly. Now they know that the gravitational pulls of galaxies, clusters of galaxies, and clusters of clusters (superclusters) create “dimples” of motion on top of this expansion. In our part of the universe, the largest pull comes from a region called the Great Attractor. And astronomers believe that the pull of the Great Attractor may be just the tip of the iceberg — many other clusters and superclusters pull and tug on our Milky Way Galaxy and, therefore, Earth.

The sources of Earth’s motion start close to home. Earth orbits the Sun at an average speed of 30 kilometers per second (km/s). Our solar system lies about halfway out along the 50,000-light-year radius of the Milky Way Galaxy and orbits the center of the Galaxy at a speed of 220 km/s. The nearby Andromeda Galaxy gravitationally attracts our Galaxy (and the Earth along with it) at a speed of 270 km/s. Our orbital motion in the Galaxy and its motion toward the Andromeda Galaxy are in different directions. As a result, they cancel each other out to some degree, resulting in a net motion of only 300 km/s. Our Galaxy, Andromeda, and some 30 smaller galaxies make up a “group” that is about 3 million light-years across, termed the Local Group. The net speed of 300 km/s

describes the motion of our solar system relative to the Local Group.

The measurement of the motions of the Local Group itself needs a reference point outside the group. Fortunately, the universe itself provides the ultimate reference point. As expertly measured by the COBE spacecraft, the universe radiates at millimeter wavelengths in the afterglow of the big bang. This radiation appears uniform across our sky with one exception: As we see it, it is a little hotter in one direction and a little cooler in the opposite direction. Most astronomers believe this difference in temperature results from the motion of the Earth, a sum of all gravitational tugs in different directions by masses near and far. These tugs result in the Local Group's moving at 600 km/s towards the southern constellation Antlia.

This motion of the Local Group means different masses in the universe pull us thither and yon. Since the mid-1970s, astronomers have been searching for the sources of this 600 km/s motion. So far they have found four main ones.

Searching Out Motions

As the universe expands, a galaxy moves away from us at a speed that is proportional to its distance from us. Researchers call this expansion motion "normal." They call motions due to the pull of gravity "peculiar." These are the dimples of motion that exist on the general expansion of the universe. To measure them, researchers first must take into account the normal expansion motion. The motions described here are the peculiar motions of our Galaxy and the Local Group.

One of the four main sources of motion is the gravitational pull of nearby galaxies. Astronomers find that the galaxies closest to the Local Group form about a dozen similar groups. These groups inhabit a long thin cylinder dubbed the Coma-Sculptor Cloud by Brent Tully of the University of Hawaii. The Coma-Sculptor Cloud is about 50 million light-years long and 5 million light-years across, with the Local Group roughly in the center. The ends of the cylinder appear in the directions of the constellations Coma Berenices and Sculptor. The galaxies in these groups pull each other around at a speed of about 100 km/s. Our Milky Way Galaxy probably has a similar-sized motion.

Stepping outward in distance reveals many galactic clouds and large clusters of galaxies. Big clusters, such as the Virgo Cluster, may contain a thousand galaxies. The Virgo Cluster lies 60 million light-years from our Local Group and sits at the center of a much larger structure called the Virgo Supercluster. The gravitational pull of the whole supercluster causes

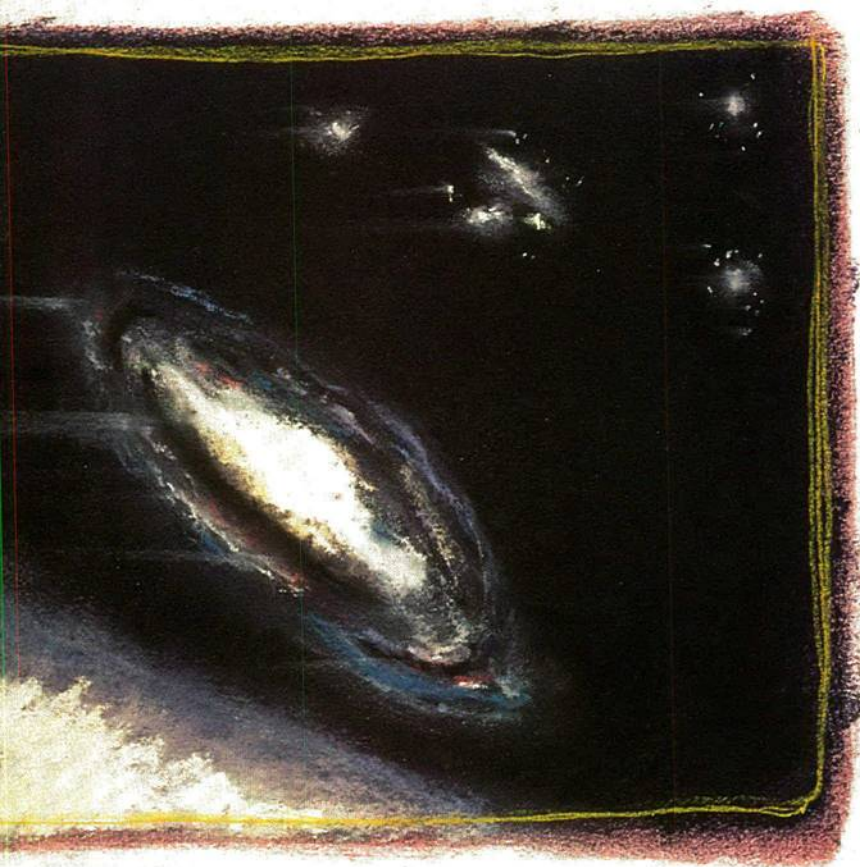


the Coma-Sculptor Cloud to stream toward it at roughly 300 km/s. This is the second of the four main motions. But it is not enough to explain our 600 km/s motion. Other sources of our motion must exist on even larger scales.

Towns and Cities

Once we start talking about larger scales, a model helps to make sense of the jumble we see. Imagine our Galaxy is a house in a subdivision (Local Group). This subdivision lies in a small town (Coma-Sculptor Cloud) that stretches along both sides of a highway that leads to a densely populated valley (Virgo Supercluster) in which lie two moderate-sized cities (Virgo and Ursa Major clusters) and other towns.

Seven years ago, a group of astronomers discovered that a large metropolis lay just beyond our horizon, a metropolis about which we previously knew nothing. This metropolis is a vast collection of galaxies that is centered 300 million light-years away in the direction of the constellations Hydra and Centaurus. The discoverers of this massive concentration (Roger Davies, Alan Dressler, Sandra Faber, Donald Lynden-Bell, Roberto Terlevich, Gary Wegner, and co-author David Burstein — known collectively as the Seven Samurai) found it by measuring the peculiar motions of galaxies in the nearby universe. Their observations showed that galaxies in the nearby universe share a streaming motion toward this great concentration of galaxies. Relative to the cosmic background, this mass concentration produces 530 km/s of the Local Group's motion. Because this motion dwarfs all the other motions, this large mass concentration has been named the "Great Attractor." Motion toward the Great Attractor forms the third of the four main motions of galaxies in the Local Group.



Our Local Group joins other groups to form the Coma-Sculptor Cloud. This Cloud moves toward the Virgo supercluster at 300 km/s.

The Hidden Metropolis

In the analogy above, all the towns and cities in the Virgo Supercluster were known because we could see the galaxies in them. Why was the Great Attractor metropolis so hard to find? Unlike the visible collection of galaxies in the Virgo Supercluster, the Great Attractor first became apparent from its gravitational pull on nearby galaxies. It was only after the Seven Samurai discovered this motion that astronomers found the galaxies that make up the Great Attractor. There are several reasons why the discovery of this large mass concentration took such a circuitous route.

The simplest reason is that most astronomers were not looking for diffuse mass concentrations. Also, the Great Attractor lies in the southern sky. Until recently, there were few large telescopes in the Southern Hemisphere, so southern galaxies were mapped comprehensively only 15 years ago. But most importantly, the vast size of the Great Attractor kept it hidden.

Whereas galaxy clusters contain many galaxies in a small region, the Great Attractor has its many galaxies spread over an enormous volume of space. As we see it, over five thousand galaxies in the Great Attractor splay across 60 degrees of the sky, covering one-third of the southern hemisphere. This low density of galaxies made the Great Attractor difficult to find.

Sizing Up the Great Attractor

An odd feature about the Great Attractor is that the vast majority of its mass comes from many small galactic groups distributed over a volume of

almost a trillion trillion cubic light-years. While the Great Attractor does contain galaxy clusters (such as those in Hydra, Centaurus, Pavo-Indus, and Telescopium), clusters provide only a small percentage of the mass of the Great Attractor. A typical cluster of galaxies has many more galaxies per million cubic light-years than the Great Attractor does, but such a cluster encompasses a volume of less than 2 trillion cubic light-years. The much larger volume of the Great Attractor wins out over its low number of galaxies per volume, so the Great Attractor has perhaps 100 to 1,000 times the mass of a typical galaxy cluster, such as the Hydra Cluster.

Astronomers estimate that all the matter within the Great Attractor has a mass of about 50 million billion suns, or 50,000 times the mass of galaxies like the Milky Way. But they only count about 7,500 galaxies in this region. So where is the other 90 percent of the mass? Perhaps it is in the form of dark matter. Researchers presently believe that about four-fifths of the mass of a typical cluster of galaxies does not radiate energy, hence its name dark matter. The estimate of the Great Attractor's mass is consistent with the division of dark and visible matter.

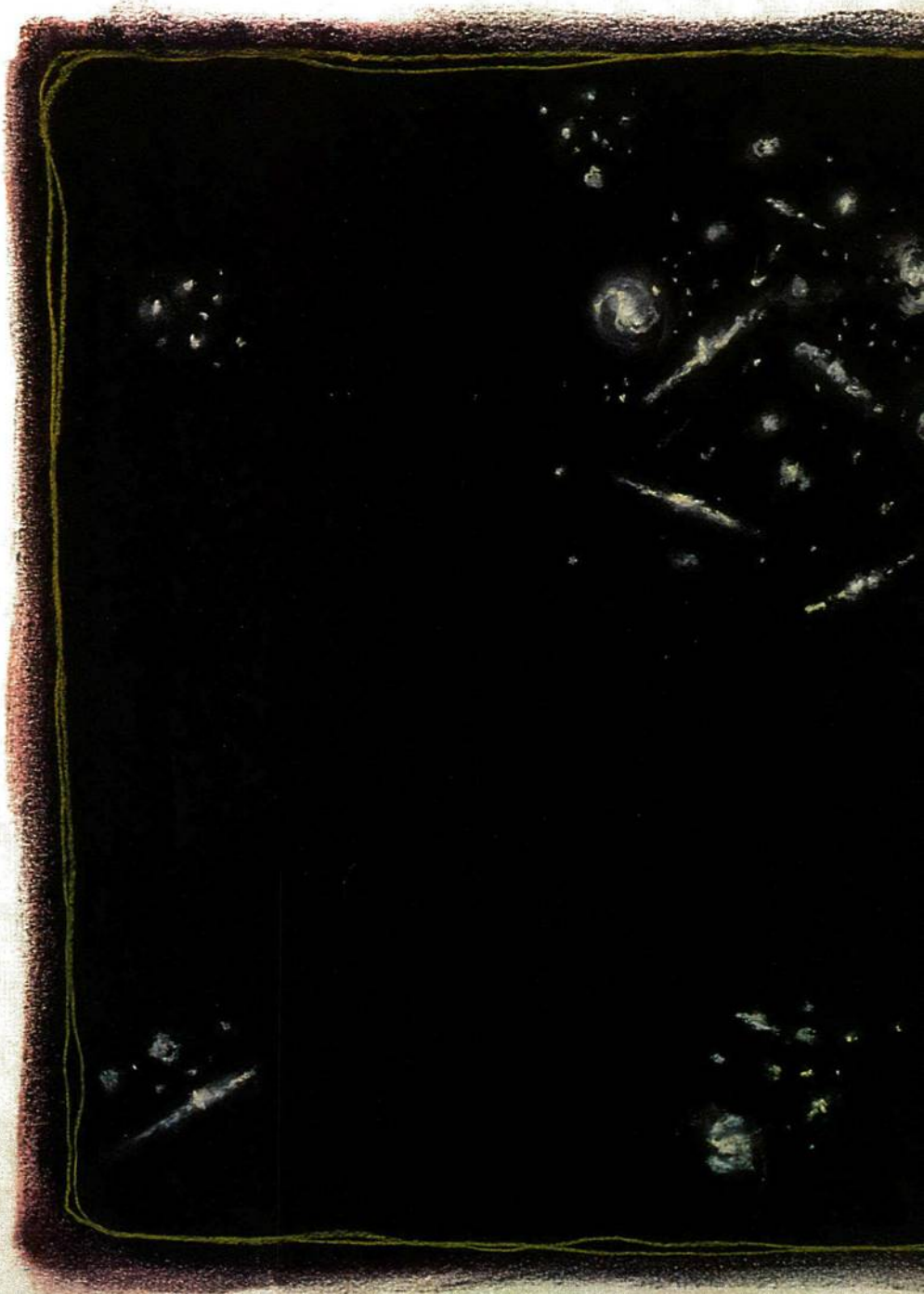
Matter, whether it is dark or light, generates gravitational pulls that produce the peculiar motions of galaxies. This is fortunate for astronomers, who use this fact to infer maps of the distribution of matter from the streaming motions they observe. Perhaps the best visual representation of matter in and around the Great Attractor comes from the theoretical models produced by Edmund Bertschinger of the Massachusetts Institute of Technology and Avishai Dekel of Hebrew University in Jerusalem.

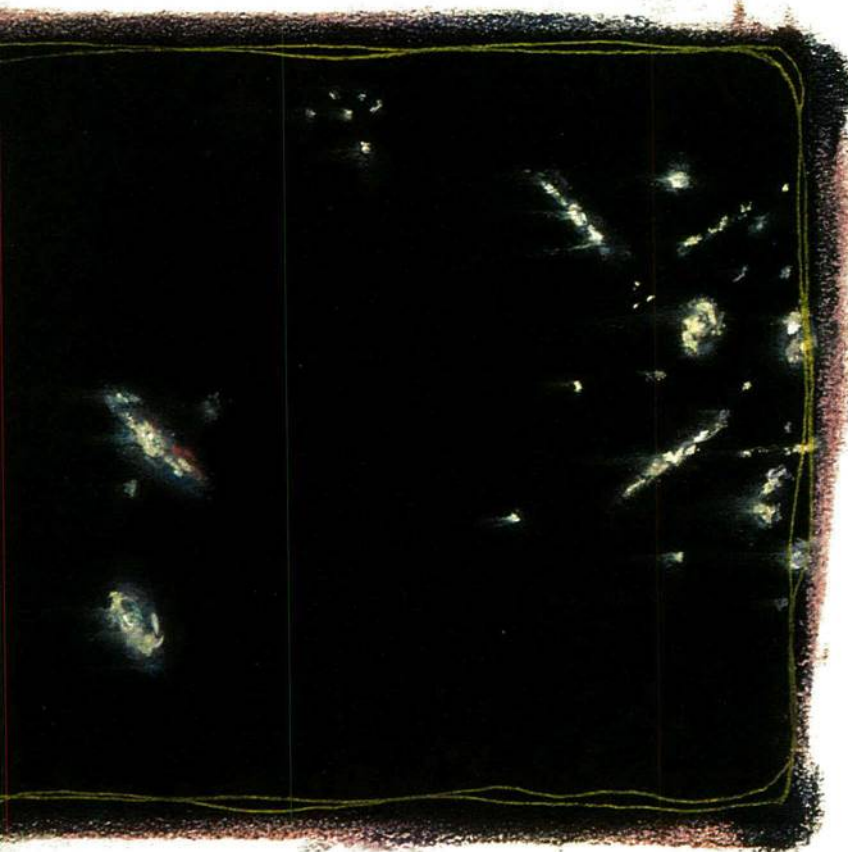
Most galaxies including those in the Local Group, Virgo Supercluster, Perseus Supercluster, and Great Attractor happen to lie along a plane called the Supergalactic Plane. Dekel and Bertschinger's models translate galactic peculiar motions into gravitational pulls and predict the relative distribution of mass within the Supergalactic Plane. (See the map on page 45.) In this map, the Great Attractor shows up as a peak. The Virgo Supercluster forms the foothills at the base of the Great Attractor's peak.

As massive as the Great Attractor is, it does not account for all of the 600 km/s motion of the Local Group. Another mass also must join in the tug of war on the Local Group.

Cosmic Tug of War

The motion of the Local Group relative to the cosmic background results from the gravitational pulls of at least three massive components: the Great





The enormous Great Attractor in Hydra-Centaurus pulls our Local Group up a "mountain of mass" at a speed of 530 km/s.

Attractor, the Virgo Supercluster, and other galactic groups in the Coma-Sculptor Cloud. These tugs occur in different directions. When astronomers summed these motions up and compared the sum with the 600 km/s motion, they found a hitherto unknown pull of 370 km/s in the direction of Canis Minor.

Identifying the source of this motion — the fourth of the main motions of the Local Group — has been difficult because observers have to look through the dust and gas in the disk of our Galaxy. This veil is hard to penetrate, so astronomers haven't identified the source of the 370 km/s motion yet.

In the town and city analogy, while the Great Attractor metropolis dominates the near landscape, other metropolises lie slightly farther away in other directions.

The Perseus Supercluster (see map), thought by many astronomers to be nearly as massive as the Great Attractor, lies nearly due east of the Coma-Sculptor Cloud and about 20 percent farther away from us than the Great Attractor. Another supercluster forms the Cetus Wall.

These mass concentrations in our three-dimensional universe engage in a cosmic tug of war on each galaxy, sometimes canceling and sometimes adding to each other. For our Local Group of galaxies, the largest mass concentration closest to us, the Great Attractor, wins the game. But as the motion toward Canis Minor shows, gravitational tugs from other large mass concentrations in the universe also affect us. Astronomers now face the challenge of mapping out these other mass concentrations.

Much Ado about Matter

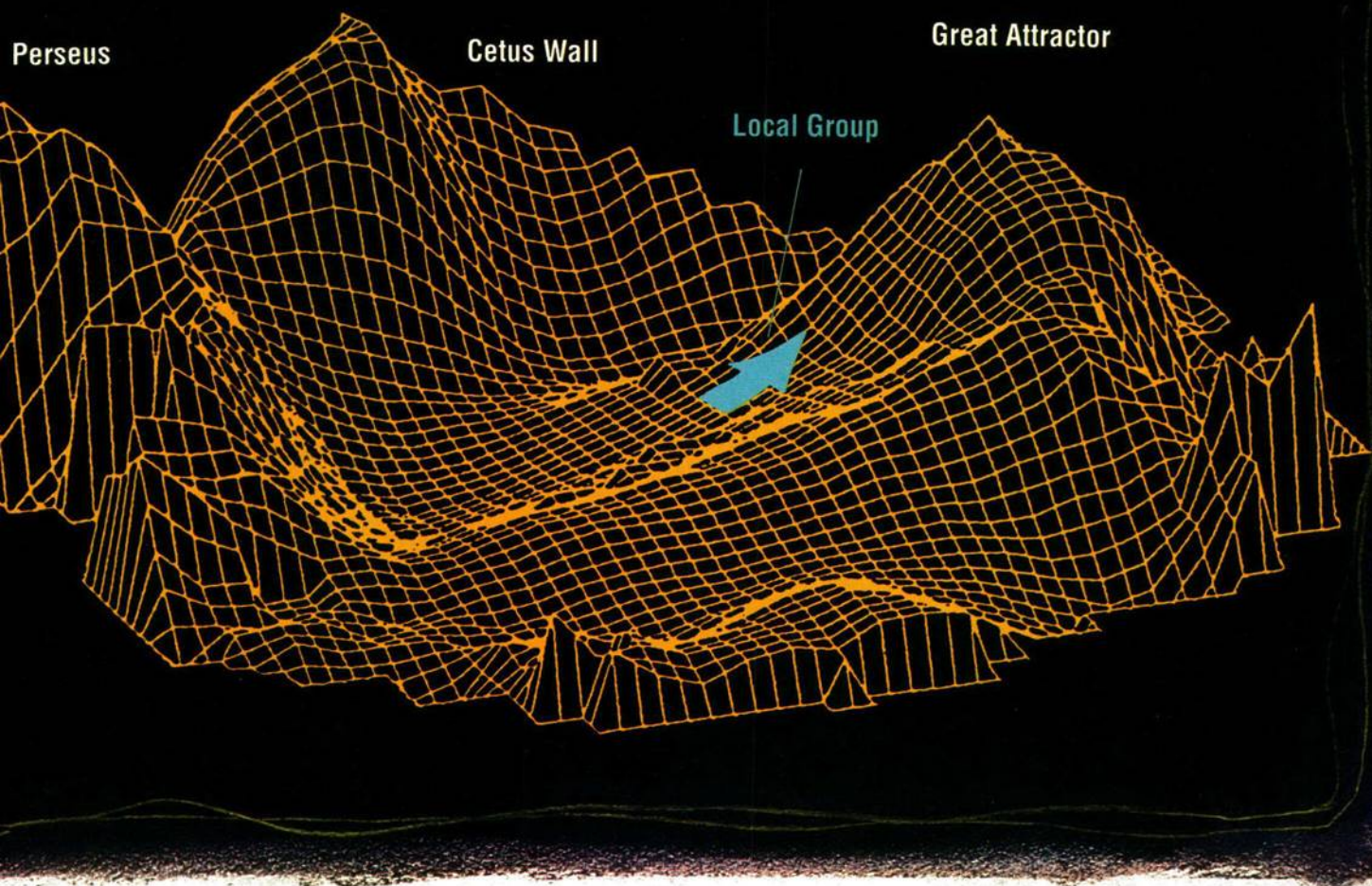
If astronomers can measure the peculiar motions of galaxies, they can produce a map that shows where mass exists in the universe. This is

but one of the goals that pushes at least 20 different groups of astronomers to measure galactic peculiar motions in various parts of the sky. A group of astronomers from the United States, Great Britain, and Italy, including co-author Dave Burstein, is attempting to measure the peculiar motions of 550 galaxies that lie three times farther away than the Great Attractor. The researchers purposefully chose galaxies in a direction away from the Great Attractor to search for the existence of large-scale motions not generated by the gravitational pull of the Great Attractor.

The lack of a single, coherent theory to simultaneously explain large structures in the universe (such as the Great Attractor) and small structures (such as galaxies) leaves room for a lot of cosmological speculation. For example, perhaps dark matter clumps together like visible matter. If so, then peculiar motions might result not only from the objects we see, but also from those we cannot see. By its nature, though, dark matter is hard to detect and few reliable results have emerged from attempts to test this idea.

There is hope, however, that new techniques will permit more accurate





measurements of the peculiar motions of galaxies. One new method, developed by John Tonry of the Massachusetts Institute of Technology and Donald Schneider of the Institute for Advanced Study in Princeton, New Jersey, promises to be one of the most accurate. The Tonry-Schneider method uses the fact that galaxies are made of individual stars to cleverly obtain the apparent brightnesses of the brightest types of stars in a galaxy. Assuming they know the luminosities of these types of bright stars, astronomers can determine the distances of the galaxies to an accuracy of 5 to 8 percent, compared with present accuracies of 10 to 15 percent. Most researchers expect that peculiar velocities of galaxies now measured with an accuracy of about 20 percent will be measured with at least twice that accuracy in the future.

However, even tenfold increases in the number of galaxies we observe and twofold increases in accuracy won't change the picture of the motions in the nearby universe. As the Seven Samurai concluded, we will not stop falling into the Virgo Supercluster and the enormous mass of the Great Attractor will unceasingly draw us toward it. □

Avishai Dekel and Edmund Bertschinger

David Burstein, an associate professor of astronomy at Arizona State University, studies galaxies and cosmology. Peter L. Manly is a freelance writer in the fields of astronomy, aviation, and computers. His article "Stand in the Shadow of an Asteroid" appeared in the January 1991 issue.

The all-sky map shows
how the sky looks at:
Midnight on July 1
11:00 p.m. on July 15
10:00 p.m. on July 31
Planets are shown
at midmonth

East

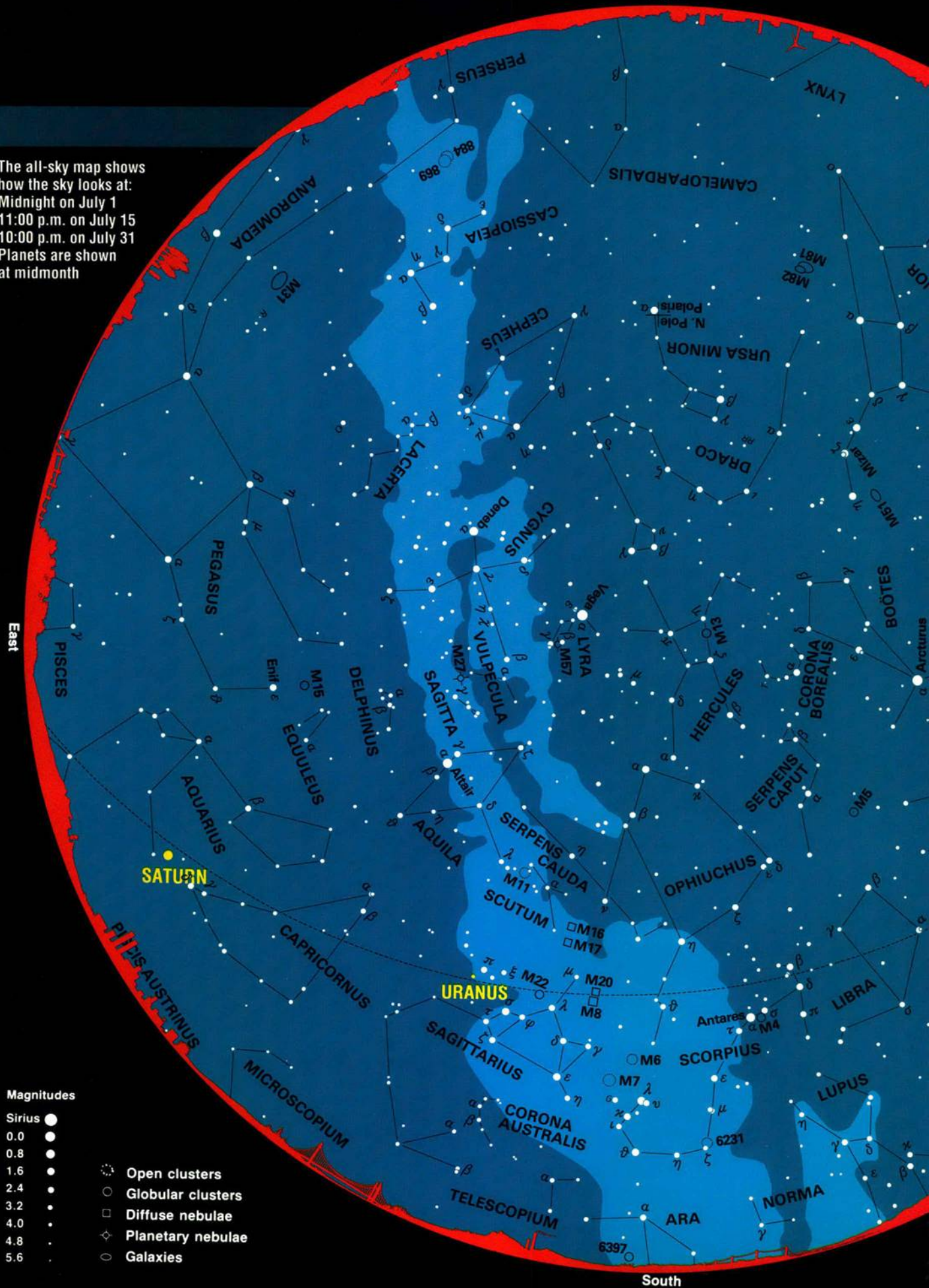
North

South

Magnitudes

Sirius ●
0.0 ●
0.8 ●
1.6 ●
2.4 ●
3.2 ●
4.0 ●
4.8 ●
5.6 ●

- Open clusters
- Globular clusters
- Diffuse nebulae
- ◇ Planetary nebulae
- Galaxies



Sky Almanac

July 1993

URANUS AND NEPTUNE REUNITE

The distant gas giants Uranus and Neptune team up in the evening sky this month. Separated by a mere 1.1° , the planets will be visible in the same low-power field of view. Moreover, Uranus and Neptune reach opposition within a few hours of each other on July 11 and 12. At that time Uranus will be visible to the naked eye as a magnitude 5.6 blue-green "star." Neptune, slightly too faint to be seen with the naked eye, will be easily visible in binoculars as a greenish dot.

JUPITER'S MOON DANCE

The King of Planets reaches quadrature this month, affording a superb view of the big planet as it eclipses its bright moons. The planet's shadow will be cast at an extreme angle relative to our line of sight, making the disappearances and reappearances of the satellites especially dramatic.

VENUS WITH YOUR BREAKFAST?

Throughout July Venus is a dazzling early morning object in the constellation Taurus. The brilliant planet shines at magnitude -4 and lives up to its "morning star" nickname as the dominant object visible in the sky. On July 27 Venus passes less than 1° north of the Crab Nebula (M1), affording astrophotographers an excellent chance at recording the close encounter.

Calendar of Events

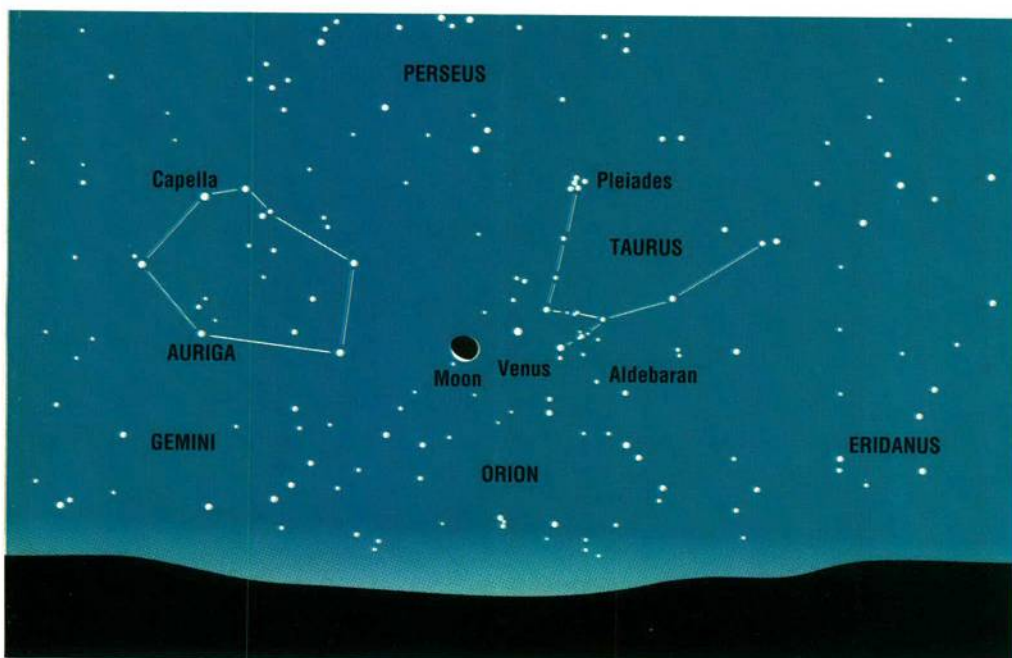
- | | |
|--|---|
| 3 Full Moon is at 7:45 p.m. EDT | 22 The Moon is at perigee (226,890 miles from Earth), 4 a.m. EDT |
| 10 The Moon is at apogee (251,289 miles from Earth), 7 a.m. EDT | The Moon passes 6° south of Mars, 11 p.m. EDT |
| 11 Last Quarter Moon is at 6:49 p.m. EDT
Neptune is at opposition, 11 p.m. EDT | 24 The Moon passes 6° south of Jupiter, 10 a.m. EDT |
| 12 Uranus is at opposition, 10 a.m. EDT | 25 Mercury is stationary |
| 14 Mercury is in inferior conjunction | 25 First Quarter Moon is at 11:25 p.m. EDT |
| 15 Venus passes 3° north of Aldebaran, 3 a.m. EDT
The Moon passes 2° north of Venus, 11 p.m. EDT | 28 The Southern Delta Aquarid meteor shower peaks |
| 17 Vesta is stationary | 31 The Moon passes 3° north of Neptune, 5 p.m. EDT |
| 19 New Moon is at 7:24 a.m. EDT | The Moon passes 4° north of Uranus, 6 p.m. EDT |

Map Art by Wil Tirion



THE MOON PASSES THE PLEIADES in the early morning of July 15. At closest approach the waning crescent Moon slides just 3° south of the bright cluster. In March 1987, the two objects were even closer in the evening sky (above).

VENUS AND THE MOON form a pretty pair in the early morning sky of July 16. At closest approach the two objects are only 2° apart, making them visible together in a binocular field of view.



TWO DISTANT GIANTS

One year ago the gas giant planets Uranus and Neptune appeared opposite the Sun in our sky. Now Earth has made yet another circuit around our local star, placing the same two slow-moving planets opposite the Sun again. Last year their oppositions came about two days apart. This year our planet passes between the Sun and Neptune only about half a day before it moves between the Sun and Uranus.

Both Neptune and Uranus reach opposition on July 12 against the stellar background of the constellation Sagittarius. When the month begins, Uranus and Neptune are separated by a mere 1.3° . They're slightly closer together when the month ends.

Because they're opposite the Sun in the sky, both Uranus and Neptune are up nearly all night. They rise in the southeast at sunset and arc slowly across the southern sky. Binoculars will aid in the search for Uranus, but once you've found the planet, you'll be able to glimpse it with the eye alone if you're observing from a reasonably dark sky. Uranus shines at magnitude 5.6. Such a relatively faint naked-eye star would not appear green in color, but Uranus with its $3.8''$ disk glows with a greenish light, steadily beaming rather than twinkling. At magnitude 7.9, Neptune is considerably fainter than Uranus. It is easy to pick out in 7x50 binoculars, in which it appears as a tiny dot of light. I always think Neptune looks more bluish than greenish. Now is a good time to contrast the colors of the two planets, because they are close enough together to be visible in a single binocular field of view. (See the finder chart on page 51.)

PREDAWN STARGAZING

The planet Venus is still easily visible in the east before dawn. It shines brilliantly at magnitude -4.1 . Venus begins the month in the constellation Taurus, forming a triangle with two prominent star clusters, the Hyades and the Pleiades. The Pleiades, also called the Seven Sisters, looks like a misty little dipper. The Hyades has the shape of the letter V. These aren't chance juxtapositions of stars in our sky, but are clusters of stars physically bound by gravity. Their stars were born and move together through space.

Because stars rise four minutes earlier each day as Earth orbits the Sun, the Pleiades and Hyades shift upward in the predawn sky as the month proceeds. Meanwhile, Venus is now sinking a bit toward the Sun each day, and as a result it skims through the Hyades cluster this month. On July 15 it lies 3° north of Aldebaran, a bright red star that lies in front of the cluster. This star represents the fiery red eye of Taurus the Bull. On July 15 and 16 you can see lovely alignments of Aldebaran and Venus with the Moon.

As the month wanes, the Pleiades and Hyades clusters continue moving up and away from Venus, and the fleeting relationship between

the clusters and the planet ends. If you keep watching, though, you'll see another stately figure appear to the right of Venus in the predawn sky. This is Orion the Hunter, sometimes called "the ghost of the summer dawn." Orion is a prominent constellation in the evening sky every winter, but it comes out of the Sun's glare in late summer. The Hunter rises on his side, with his famous belt of three moderately bright stars pointing straight up. Seeing the bright stars of Orion come up out of the midsummer dawn can be a spine-tingling experience, so treat yourself to it this year.

JULY'S PLANETS

You might be able to glimpse **Mercury** low in the west shortly after sunset in the first few days of July. It appears as a surprisingly bright star with a warm, pinkish color near the western horizon.

Thereafter the innermost planet sinks into the Sun's glare and out of sight. It passes between Earth and the Sun on July 14 only to return to the predawn sky before the month ends. Watch for Mercury to come up out of the dawn. It'll pop into view one morning to the lower left of the planet Venus. Mercury shines at magnitude 1.1 on July 30. It will climb higher in the sky and get brighter before reaching greatest western elongation in early August.

Mars can be found midway up in the west after sunset. It sets about three hours behind the Sun. Mars is far across the solar system now. It's 17 light-minutes away, nearly as distant as it can be. As a result, it appears inconspicuous at magnitude 1.6. Mars is now sinking slowly toward the Sun's glare, but it'll take a long time to disappear. It'll finally leave our evening sky this autumn.

Mars is in Leo when the month begins, not far from Regulus, Leo's brightest star. Regulus shines at magnitude 1.4, so it is only a bit brighter than Mars now. As the month passes, Regulus sinks out of sight, while another, much brighter object draws closer to Mars from above.

This is **Jupiter**, which is following in Mars' footsteps across the sky, fading in brightness and edging toward the Sun's glare. This month the giant planet dims to magnitude -1.9. It will sink out of sight even sooner than Mars. Because this is the case, at some point Mars and Jupiter must pass each other in the sky. Their conjunction comes in September. Watch the evening sky around July 22-24 to see the young Moon sweep near these planets.

The glorious ringed planet, **Saturn**, comes up in the east-southeast about three hours after sunset at the start of this month. By month's end it is rising at the end of evening twilight. Saturn is heading toward an August opposition, when we'll pass between it and the Sun. As a result, this month its brightness increases from magnitude 0.6 to 0.5.

You need a telescope to see Saturn's rings, but the eye alone shows Saturn as a steadily shining "star" of a lovely golden color. Saturn is still in the constellation Aquarius. Look for the planet near the Moon on the night of July 7/8.



THE MILKY WAY ARCHES OVERHEAD on July evenings, bringing with it some of the most spectacular star clusters and nebulae in the sky. Explore the Milky Way with a pair of binoculars this summer. The photo was taken in 1986 and shows Mars at lower left.

Venus is rising a bit later now. It comes up about three hours before the Sun in early July. Venus shines at magnitude -4.1 and appears as an unmistakable beacon in the predawn sky. The planet lies 3° north of Aldebaran on July 15. The Moon passes near Venus the following day. Look for lovely and photogenic alignments of planet, star, and Moon for several days around these times.

THE STARRY SKY

Most of the sky's brightest stars are distinctive and solitary. We gaze up at them and perceive them as singular objects. But many people see the brightest star in the constellation Aquila the Eagle as part of a trio.

The star — called Altair — has a fainter companion on either side. Altair, Tarazed (Gamma [γ] Aquilae), and Alshain (Beta [β] Aquilae) are sometimes called the Family of Aquila. You will see these three stars this month ascending in the southeast each evening. As Martha Evans Martin wrote in her book *The Friendly Stars* in 1907, it is as if these three are "walking the Milky Way hand in hand and three abreast."

The rest of the constellation Aquila can be seen from a country location. Some people compare its shape with that of a baseball diamond, with Altair approximately at home base. I prefer to see this constellation as a mighty bird, with wings outstretched, flying north through the starry band of the summer Milky Way. Aquila lies along the celestial equator, the imaginary line around the sky above Earth's equator. As a result, its stars rise nearly due east and set nearly due west.

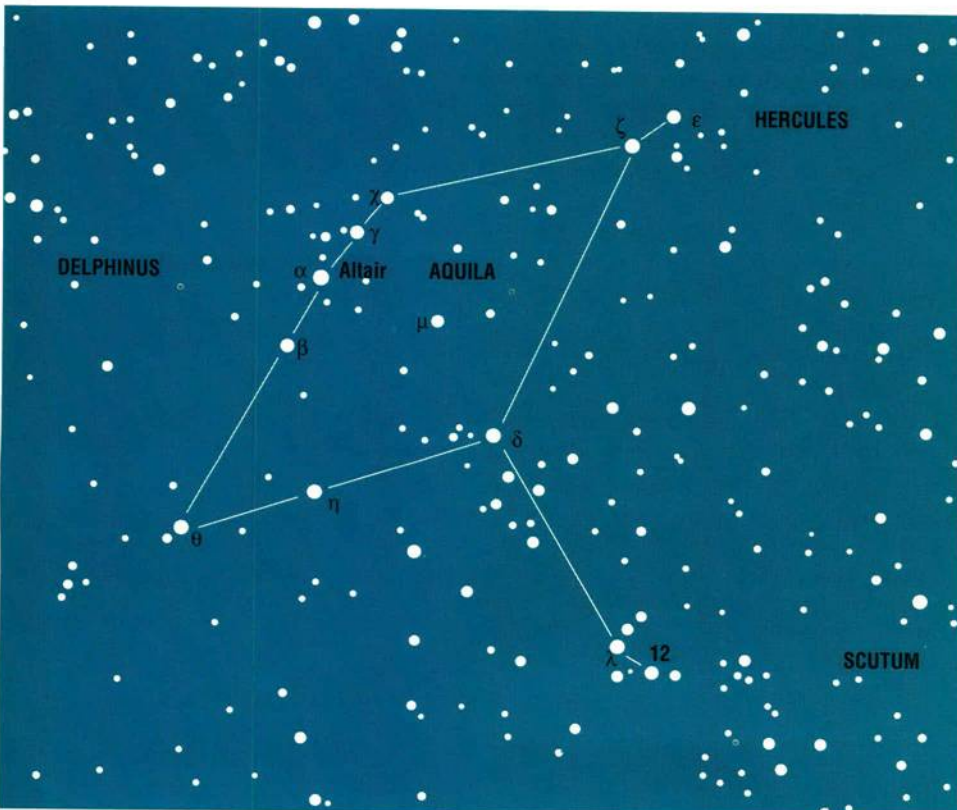
Roman stargazers considered Aquila the Eagle of Jupiter. The Eagle delivered thunderbolts to Earth for use against Jupiter's enemies. Once when Jupiter needed a new waiter or cup-bearer to bring fresh nectar to the gods, the Eagle flew to Earth and swept over the land until it spied a beautiful youth tending a flock of sheep. This was the Trojan prince Ganymede, whom the Eagle carried to Mount Olympus to be cupbearer to the gods.

Altair shines at magnitude 0.8, ranking it as the 12th brightest star in the whole sky. Its name comes from an Arabic word meaning "flying eagle." It is a white main sequence star, probably with no more than twice the Sun's mass but with ten times the Sun's luminosity. These more luminous stars pay for their great glory with their short life span. Altair is expected to remain on the main sequence for about two billion years, in contrast to our Sun's 13 billion years.

Altair's simple beauty reminds me of Martha Evans Martin's remark, "The stars that we love best are the ones into whose faces we can look for an hour at a time, if our fancy so leads us." □

Deborah Byrd writes and produces the daily "Earth and Sky" radio series. It now can be heard on over 240 radio stations.

AQUILA THE EAGLE is one of the brightest star groups in the summer Milky Way. Its brightest star, Altair, is one of three beacons in the Summer Triangle asterism.



TWO PLANETS PASSING IN THE NIGHT

Uranus and Neptune this month undergo a rare conjunction during which both are at opposition on the same day. When Neptune was discovered in 1846, such a conjunction had occurred only twenty-five years earlier. Of course, nobody knew about Neptune then, but Uranus certainly was well known. Neptune surely must have been seen many times among the stars of the Milky Way in Sagittarius. Early in that year, this region of sky rose a couple of hours before the Sun and should have been visible from most places in the Northern Hemisphere, though it was at a southerly declination for observers in England and France.

Perhaps an intrepid astronomer poked his telescope through a tower window on the morning of February 22, 1821, and dutifully noted Uranus' position, a few degrees northwest of Lambda Sagittarii (the top star in the Teapot's lid). On that same morning, Neptune lay a mere 1.2° northeast of Uranus, an 8th-magnitude blue "star" that, had anyone noticed, moved subtly against the starry backdrop from night to night.

The two worlds remained close all that year, never treading more than 1.5° from each other. In July, when the planets were well up in the evening sky — and there was no television to distract astronomers from the business of discovering distant worlds — the two planets were separated by only 1.4° . Still, Neptune was swept over time and again. The year 1821 must surely go down as a time of missed opportunities in astronomy.

Returning to the present, during July, Uranus and Neptune lie a little over 3° south of Rho¹ Sagittarii, or $3\frac{1}{2}^\circ$ southeast of magnitude 2.8 Pi Sagittarii (check out the finder chart above). We are fortunate that this year the two planets will pass even closer to each other than they did in 1821. At opposition on July 12, Uranus and Neptune lie only 1.1° apart, with Neptune to the north. Both planets can easily be seen in a low-power field of view. Uranus appears as a blue-green disk, Neptune a blue dot. An eyepiece with a 50° apparent field of view at 40x will just encompass the region. At higher magnifications, a mere shift north and south in declination allows you to compare the planets' brightnesses and colors. At opposition, Uranus is clearly the brighter, more striking object with a magnitude of 5.6 and an apparent diameter of 3.8 arcseconds. Neptune glows at magnitude 7.9 and has an apparent diameter of 2.3 arcseconds.

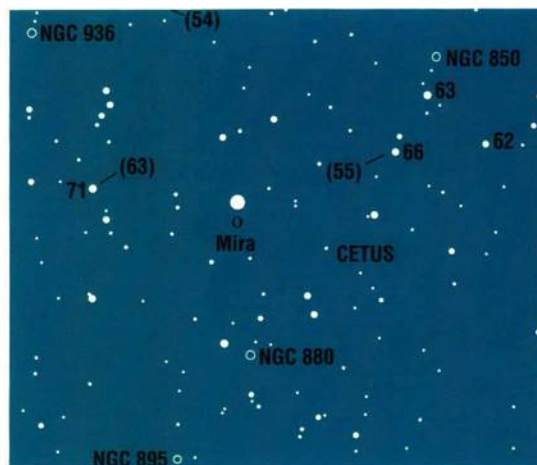
The challenge with these outer planets is to see atmospheric features. If that's your goal, you can virtually rule out Uranus. Recall that the Voyager 2 images showed Uranus as a featureless cue ball, save for the blue-green haze in its upper atmosphere. Apparently Uranus radiates little more than the heat it absorbs from sunlight, making Uranus a sphinx among planets.

What about Neptune? For years some observers have reported seeing



OPPOSITION FOR URANUS AND NEPTUNE comes on July 12, when the two gas giants are separated by a mere 1.1° in northeastern Sagittarius. A wide-field telescope shows both Uranus and slightly fainter Neptune within the same field of view.

VARIABLE STAR MIRA (Omicron Ceti) shines near its maximum brightness of about 3rd magnitude throughout July. In this binocular field, the numbers in parentheses indicate magnitudes of nearby stars with decimals omitted.



dark features on the disk from time to time. And, indeed, the Voyager 2 images showing the prominent Great Dark Spot seem to confirm this. The only hitch with these reports is that Neptune's great distance from Earth and its small diameter conspire to make spying these elusive markings more than a challenge. Neptune doesn't even begin to look definitively disklike until you reach magnifications of 175x or more.

JUPITER'S INS AND OUTS

Jupiter is currently exhibiting its greatest phase angle for the year (even more overt than last January's phase angle if, indeed, you can call 10.7° overt). Try studying the planet closely at high magnifications — 30x to 40x per inch of aperture. (Excellent seeing conditions are not crucial here — you're looking for a global feature, not surface detail.) You may notice that one limb looks softer than the other and that the disk itself doesn't look quite as symmetrical as it usually does. This phase effect is simply a result of our seeing the planet lit more from the side than usual, because the Sun-Earth line now forms an almost-right-angle with the Earth-Jupiter line. This planetary configuration is known as quadrature, and for Jupiter it always occurs about three months before and after opposition.

If seeing Jupiter's phase doesn't do much for you, how about watching the planet's shadow eclipse its moons? Eclipses of the Galilean satellites are easier to see at quadrature, when the planet's shadow is cast at an extreme angle to one side of the globe, and the satellites pass alternately into and out of this zone of darkness. This is real "action astronomy" that requires you to keep a sharp eye out for a disappearing or reappearing moon. I suggest using moderate to high magnification, but not so high you lose sight of the big picture. Because Jupiter's shadow is cast east of its disk after opposition, that's where all the action will occur. (East is to the right of the disk in a Newtonian reflector, and to the left in catadioptric and in refracting telescopes equipped with a star diagonal.)

One rather fine example of such an event occurs July 4 at 3h15m UT (evening of July 3 in the Western Hemisphere) when Europa disappears into Jupiter's shadow just after it comes out from behind Jupiter's limb. Unfortunately, this occurs right at sunset along the Pacific Coast. Only the Eastern, Central, and easternmost Mountain time zones are favored for the reappearance of Io on July 12 at 2h58m UT (evening of July 11 in the Americas). A reappearance event involving Ganymede occurs July 15 at 3h33m UT (evening of July 14 in North America, which again

is borderline for the West Coast). One of the best-timed events for the West Coast occurs July 22 at 4h55m UT (evening of July 21 in North America), when Ganymede disappears into Jupiter's shadow. And on July 29 at 2h41m UT (evening of July 28 in the Western Hemisphere), Europa reappears from Jupiter's shadow for observers in Eastern and Central time zones.

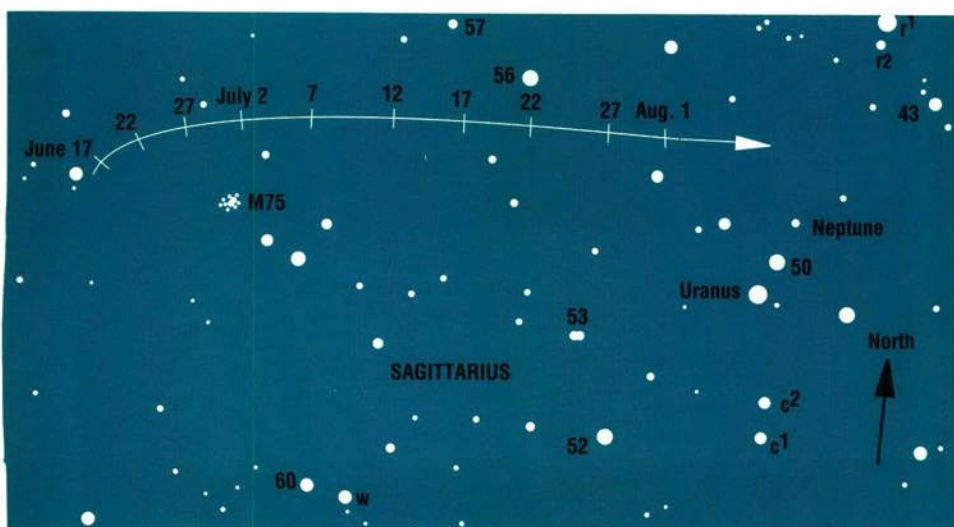
ASTEROIDS IN THE EYEPiece

The asteroid **15 Eunomia** is slightly larger than the better-known minor planet Juno. Still, Eunomia is unknown to many amateur astronomers. Discovered in 1851, Eunomia has an orbit

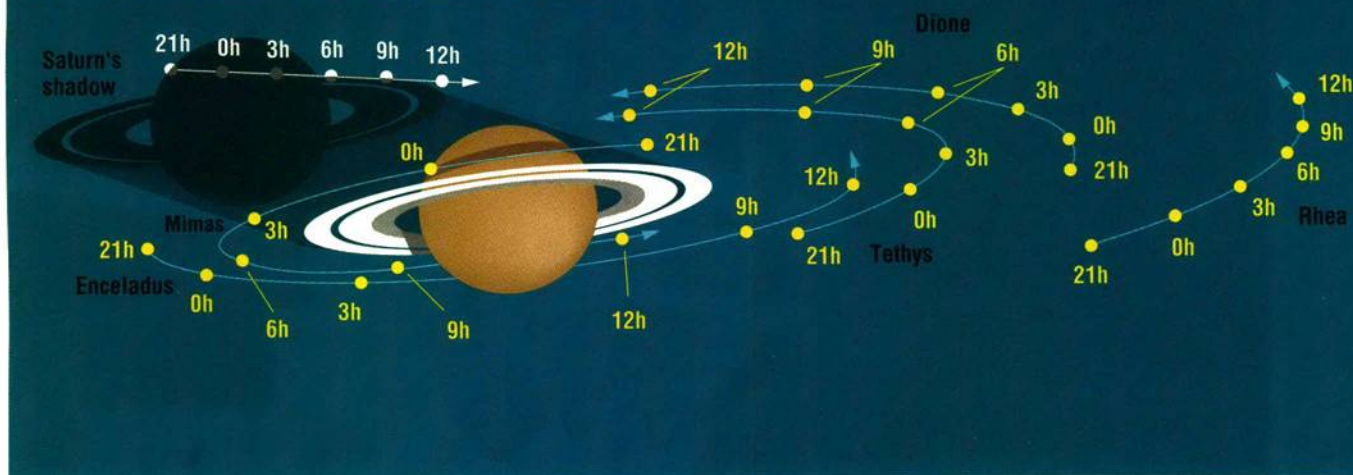
COORDINATES FOR 15 EUNOMIA

Date	R.A. (2000)	Dec.
June 17	20h14.1m	-21°34'
June 22	20h11.1m	-21°25'
June 27	20h07.4m	-21°15'
July 2	20h03.2m	-21°06'
July 7	19h58.6m	-20°57'
July 12	19h53.5m	-20°48'
July 17	19h48.3m	-20°38'
July 22	19h43.0m	-20°27'
July 27	19h37.8m	-20°16'
August 1	19h32.8m	-20°04'

ASTEROID 15 EUNOMIA cuts through northeastern Sagittarius in July, when it peaks at magnitude 8.4. Find Eunomia by sketching its starfield and then returning the next night for a second observation. The "star" that moved is it.



IAPETUS' PATH THROUGH SATURN'S SHADOW — JULY 20/21



ASTRONOMY: Phil Kirchmeier after M. Soma

that is more eccentric than that of the largest known asteroid, Ceres, as well as slightly more inclined, but it is also nearer and thus gets fairly bright when the geometry is right, as it is this month. Eunomia comes to opposition on July 17, when it reaches a peak magnitude of 8.3. Coincidentally, it lies just east of Uranus and Neptune in the star-crowded Milky Way of Sagittarius. On that evening, Eunomia lies about one degree southeast of 56 Sagittarii. Given that Uranus and Neptune are at opposition on July 12, it might add a feather to your observing hat to see an asteroid and Uranus and Neptune near opposition on the same night.

Because Eunomia is moving slightly toward the Sun in its orbit, it is actually nearest to Earth on July 24. By August 1, it lies about 1.5° north of Neptune. Look for the asteroid using the finder chart opposite. The "star" at the asteroid's position that moves with respect to the background stars from night to night is Eunomia.

VENUS GRACES TAURUS IN THE MORNING

Venus remains incredibly bright in the east, but it is also quite low. Nevertheless, in the brief window between Venus-rise and dawn, this "morning star" passes through an interesting part of the winter Milky Way, creating an opportunity for near hits of some fairly bright stars and a well-known deep-sky object — the Crab Nebula.

Now well past elongation, Venus has just about lost its half-moon appearance in the telescope in favor of a gibbous phase. The planet is also growing smaller in apparent size. On the morning of the 13th, Venus slips 24 arcminutes southwest of the magnitude 3.5 star 74 Tauri. On the 27th, Venus encroaches on the Crab Nebula, lying 47 arcminutes to the north. This is an opportunity to try to get both of these objects in a single telescopic field of view. Astrophotographers might even try to record this unusual composition on film, but be forewarned that the extreme brightness differences will make this a difficult shot. Venus will have to be overexposed, and the 8th-magnitude Crab will pale by comparison. Finally, one day later, Venus skims a mere 16 arcminutes north of 3rd-magnitude Zeta Tauri, the southernmost end-star in the bull's horn. □

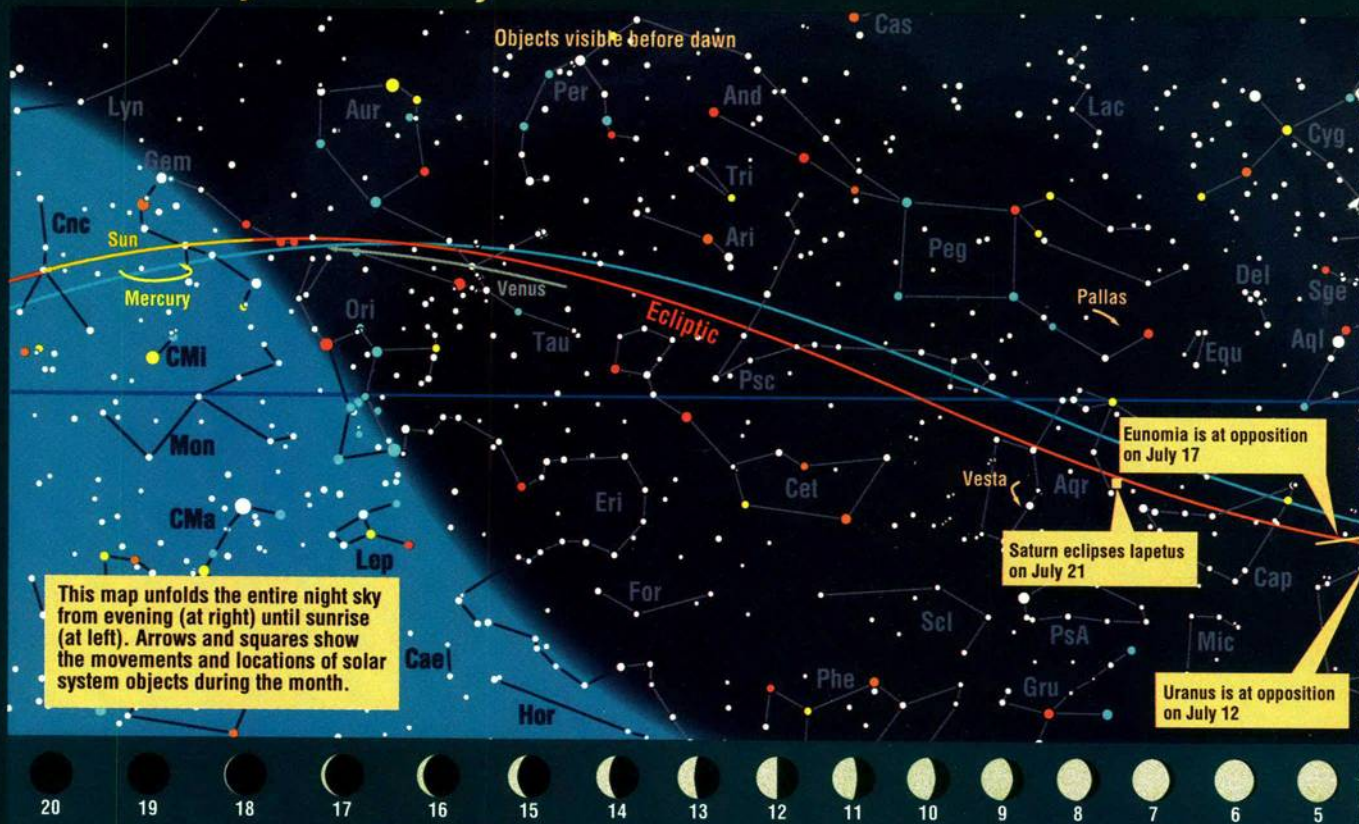
SATURN ECLIPSES IAPETUS on the morning of July 21. The planet's disk and A Ring will intermittently block sunlight from reaching the moon. South is shown at top and east at right to match the view in an inverting telescope. (Times given are universal times. Subtract 4 hours to convert to EDT, 5 hours for CDT, 6 hours for MDT, and 7 hours for PDT.)

IAPETUS IN SATURN'S SHADOW

Phenomenon	Time (UT)
July 20	
Enters Saturn's shadow	21h16m
July 21	
Leaves Saturn's shadow	5h08m
Enters A Ring shadow	5h13m
Leaves A Ring shadow	9h38m

Jeff Kanipe is the editor of *Star Date* magazine, which is published by McDonald Observatory at the University of Texas at Austin, and writes an astronomy column for the *Associated Press*.

The Solar System July 1993



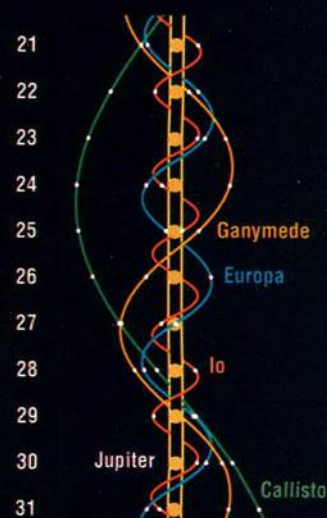
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

PLANETS	W	E	S	N
Date				
Magnitude				
Angular Size				
Illumination				
Distance (AU) from Earth				
Distance (AU) from Sun				
Right Ascension (2000.0)				
Declination (2000.0)				

MERCURY	MERCURY	VENUS	VENUS	MARS
July 1	July 31	July 1	July 31	July 15
2.0	0.9	-4.2	-4.0	1.6
10.6"	8.5"	19.3"	15.3"	4.5"
15%	26%	60%	72%	94%
0.635	0.788	0.865	1.091	2.086
0.466	0.367	0.728	0.725	1.635
7h59.9m	7h23.0m	3h32.3m	5h50.8m	10h58.1m
18°24'	19°17'	16°14'	21°37'	7°34'

Jupiter's Moons

Dots display positions of Galilean satellites at 4 UT on date shown. South is at top to match the view in a telescope.





JUPITER

July 15
-1.9
35.0"
99%
5.630
5.454
12h29.7m
-1°51'



SATURN

July 15
0.6
18.4"
100%
8.988
9.820
22h08.4
-13°01'



URANUS

July 15
5.6
3.8"
100%
18.590
19.605
19h27.7m
-22°24'

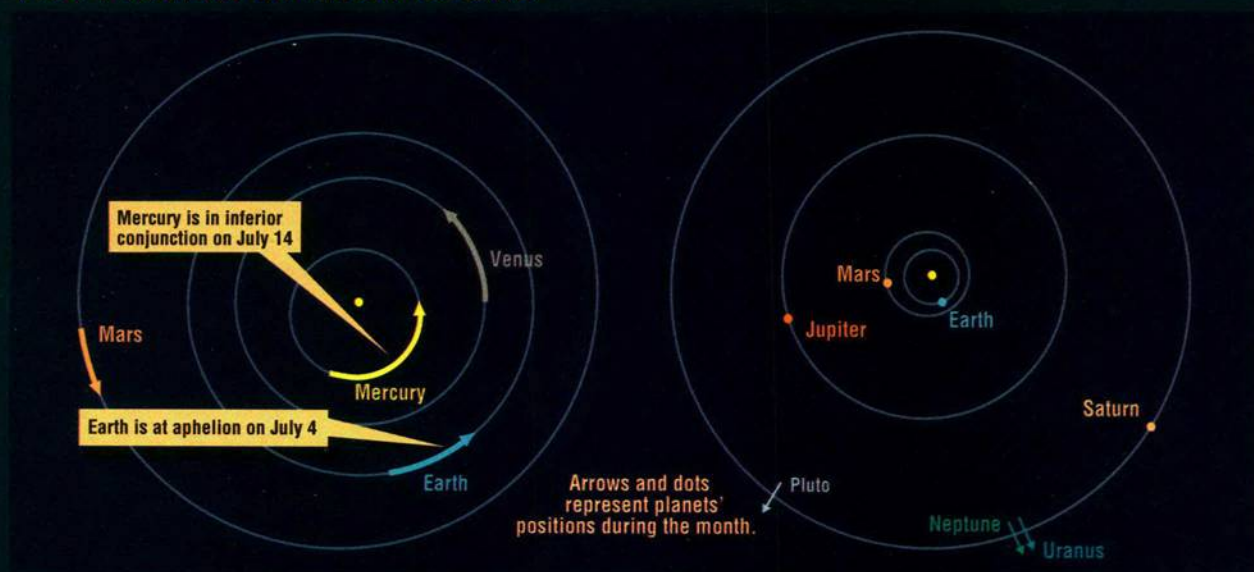
NEPTUNE

July 15
7.9
2.3"
100%
29.169
30.184
19h25.1m
-21°18'

PLUTO

July 15
13.7
0.1"
100%
29.231
29.741
15h36.6m
-4°24'

The Planets in Their Orbits



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Getting Focused on Sharper Photos

You've selected the best equipment, film, and exposures. But your photos still come back with stars that look like big fuzzballs. What's wrong?

by Chris Schur



When you take an astrophoto, focusing the image would seem to be an obvious first step. It is certainly a critical step for acquiring great images. And yet, surprisingly, many astrophotographers pay little attention to this fundamental technique. Otherwise skilled skyshooters often take a casual attitude toward focusing, an approach which inevitably leads to only a fraction of their astrophotos having crisp images. A little extra effort at the telescope could have produced sharp and repeatable results and photos with the dramatic impact of professional observatory images.

Some of the techniques for sharply focusing your astrophotos may seem unusual, but they work so well you will never go back to your old way of focusing again.

Focusing By Eye

A star is in perfect focus when the maximum amount of starlight is concentrated into the smallest area possible on the film. The size of the star's image is limited by factors such as the wave nature of light, the optical quality and collimation of your telescope, and the steadiness of the atmosphere or "seeing" conditions.

For piggyback photography with telephoto lenses and Schmidt cameras, the smallest diameter stars (the dimmest stars) will measure less than 0.001 inch across on the film — when they are in proper focus. For prime focus shots through telescopes, good focus will usually yield stars less than 0.003 inch in diameter on the negative. While this may seem very small, on an 8x10 print these stars will grow to over 0.015 inch across and no longer be pointlike. But this is still small enough to yield an impressive print. The "snap" you see in a well-focused print or slide is the result of pointlike star images. Bloated star images are a sign

of at least one of several problems — poor seeing, poor optics, bad guiding, or bad focus.

The method most astrophotographers use today for focusing their deep-sky shots is the worst for achieving consistently sharp images. All too often I see a budding astrophotographer attach a camera to an adapter, slide it into the focuser, and center a bright star. The photographer then peers into the camera's viewfinder and proceeds to rack the focuser in and out to minimize the size of the star on the focusing screen. Convinced the camera is now in focus, the photographer then pans over to the nearby subject, composes the frame, and begins the exposure.

What's wrong with this method? If you were to measure the smallest star diameters on a series of negatives focused this way, you would inevitably see a large variation in star sizes and quality of focus. My experience with this method shows that only one out of five or ten exposures is close to the correct focus. Determining exact focus by trying to minimize a dim fuzzball doesn't work because your eye can't distinguish between a precisely focused image and a nearly focused one. In addition, if your eye has any astigmatism, as most people do when their dark-adapted pupils are wide open, the star won't even appear pointlike, but as an irregular shape with no clearly defined minimum size.

Variations of ten thousandths of an inch in focus depth are typical for astrophotos that have been focused by simply looking into a camera viewfinder. This is ten times the tolerance allowed for sharp pictures. For the best results, the film should be positioned no more than one thousandth of an inch from the focal plane of the telescope.

Focusing to within 0.001 inch demands a focuser capable of very fine

adjustments. The rack-and-pinion style of focuser is one of the poorest choices for prime-focus astrophotography. Many units have large amounts of slop, and can't be racked in and out by the one-thousandth-of-an-inch movements essential to home in on crisp focus. Some focusers actually slide in or out during the exposure as the telescope pivots across the sky. The units with helical-cut rack gears available on some telescopes are better, but still fall short of the requirements for critical astrophotography.

I've found only one type of focuser allows a large range of precise movements, can be locked down without focus shift or slop, and will not move in or out during the exposure. That is the rotating spiral threaded focuser. Several commercial firms carry some good units, but beware of the "non-rotating" types. I've found them to exhibit plenty of slop.

The Magnifier Method

How do you tell when you have focused accurately? Astrophotographers commonly use one of four methods at the prime focus of a telescope: focusing by eye alone, using a focus magnifier, taking trial-and-error photographs, or using a knife-edge focuser. Because the eye by itself cannot achieve repeatable sharp clear focus, we're left with three techniques.

The simplest of these is to use a focus magnifier. The idea is to supplement the human vision at the camera viewfinder with a small low-power lens. By magnifying the view of the camera's ground glass screen, small differences in focus become more obvious.

Focus magnifiers are available to fit the viewfinders of most cameras, either as clip-on devices or, in the case of cameras with interchangeable finders, as accessories that replace



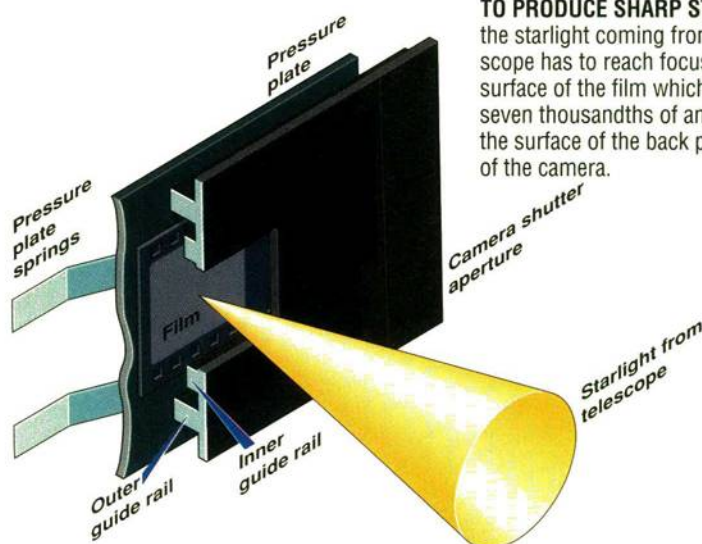
CAMERA ACCESSORIES such as add-on magnifiers and special focusing screens can help you get sharp astrophotos. But for the best results, such as the author's ultrasharp image of part of the North America Nebula, many astrophotographers prefer a technique called knife-edge focusing. Photo by Darla Gawelski.

the normal pentaprism viewfinders.

As a low-cost alternative to buying a high-power magnifier for your camera, you can make your own. The simplest way is to make use of a spare 6x30 finderscope you may have lying around. Modify it so that it will focus six to eight feet away. You can do this by either inserting a very weak lens ahead of the front lens of the finder or by unscrewing the front lens to lengthen its distance from the eyepiece. The ground glass of a 35mm camera as seen through the camera viewfinder appears at a focus distance of six to eight feet. So your modified finderscope will magnify the image on the ground glass just like it was a real image six to eight feet away.

Set up your magnifier in the daytime first. Use it to look into the camera's viewfinder at a distant scene and focus as sharply as possible on the ground glass or the edges of the split-image prism at the center of the viewscreen. Your makeshift magnifier will then be set for night work for focusing astrophotos.

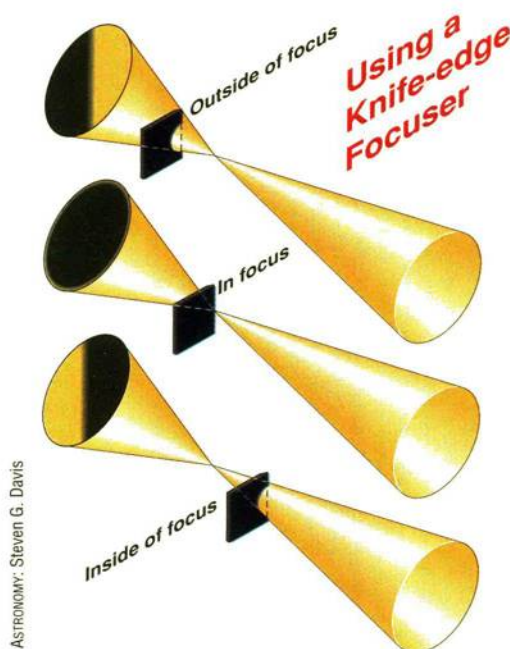
This method works well for photos of the Moon and planets where the images are bright. Enlarging the image six times provides a large, clear image on which to focus. For fuzzy-edged Jupiter and Saturn, however, try using their moons for focusing. When the moons are sharp points, the main disk of the planet will also be in focus. For a crescent Venus, focus on the tips of the cusps. For Mars use the edge of the other disk.



TO PRODUCE SHARP STAR IMAGES, the starlight coming from the telescope has to reach focus at the front surface of the film which sits about seven thousandths of an inch above the surface of the back pressure plate of the camera.

FOCUSING TIPS

- ✓ When you advance the film, apply tension to the rewind crank. This will help keep the film flat.
- ✓ Focus on 2nd- or 3rd-magnitude stars. A 1st-magnitude star is so bright you can't tell when it is in precise focus.
- ✓ Refocus your camera at least once every hour.
- ✓ Refocus after moving the telescope across the sky. The shift in weight can flex the tube and shift the optics.
- ✓ Tighten every nut and bolt in your tube assembly. Use silicone adhesive in areas where applying too much pressure on support clamps would stress the optics.
- ✓ Switch to an aluminum or steel tube. Fiberglass and cardboard tubes can sag as the telescope moves or shift focus with changes in temperature and humidity.
- ✓ Wait for nights of good seeing. When star images move or pulsate more than 2 arcseconds, star images will be noticeably larger.
- ✓ When using filters, select a 1st-magnitude star and focus through the filter. (Filters shift the focus point back several thousandths of an inch.)
- ✓ When using deep red hydrogen-alpha-pass filters, use the knife-edge method. Focusing on a ground glass screen is not precise because the eye cannot focus very well on deep red stars.
- ✓ Use a fine-grained film. Black-and-white Tech Pan produces the smallest star images.
- ✓ When hypering Kodak Tech Pan film, use low levels of heat and long hypering times. This will reduce film curl which can throw the edge of the frame out of focus.



ASTRONOMY: Steven G. Davis

KNIFE-EDGE FOCUSERS

work by slicing through the cone of light coming from a star. When the knife edge is in front of or behind the focal point, the disk of light seen through the telescope darkens from one direction. When the knife edge is at the precise point of focus, the entire disk darkens instantly.

The Moon provides many clear targets and sharp patterns on which to focus. Along the shadowed terminator look for sunlit peaks that are small, starlike, and easy to focus on. For solar photography, the limb is the only choice for a focus edge. Don't use sunspots because they usually have ill-defined edges.

However, you may find that bright targets such as the Moon and Sun will look surprisingly dim and grainy when viewed through a camera on a telescope. To make it easier to see telescopic images through your camera's viewfinder you should switch to a focusing screen designed for photography with long telephoto lenses. Not all cameras have interchangeable screens, but those that do often have plain ground glass screens available as options. Check your camera's accessory catalog and select the finest ground glass screen you can. The series of Intenscreens made by Beattie and available for a variety of cameras work well and provide brighter and sharper images than do most standard camera screens.

For lunar, planetary, and solar photography some astrophotographers use a focusing screen which has a clear center spot etched with crosshairs. When looking through a focus magnifier, you center the planet on the clear spot then shift your eye back and forth. If the planet moves in relation to the crosshairs, the telescope is out of focus. When the crosshairs and planet remain stationary when you shift your gaze the telescope is focused. This so-called

"aerial image" technique is useful only when the object is bright enough to see the crosshairs silhouetted against it. I have not had much success with aerial image focusing, but you may find the technique useful.

When coupled with a finely ground focusing screen, the magnifier method is much better than the eye alone. For the coarser ISO 1000 speed films, this method can produce good results. But for fine-grained films a focus magnifier still produces an unacceptable variation in the sizes of the smallest stars from negative to negative. For critical deep-sky shots, I recommend one of the two other focusing methods.

The Photographic Method

A precise method of focusing sometimes used at observatories involves taking a series of exposures at the telescope at various settings of the focuser. This photographic technique requires a focuser with a micrometer scale on it to indicate its position and to allow you to consistently reset the focuser to a predetermined spot. The focus position that produces the sharpest photos is the one you use for subsequent shots.

This technique takes several nights of trial-and-error efforts and works best for permanent observatory setups. For most portable telescopes it is simply not practical. The photographic method, however, is an excellent way to check the focus of the wide-angle and telephoto lenses you intend to use for piggy-back photography.

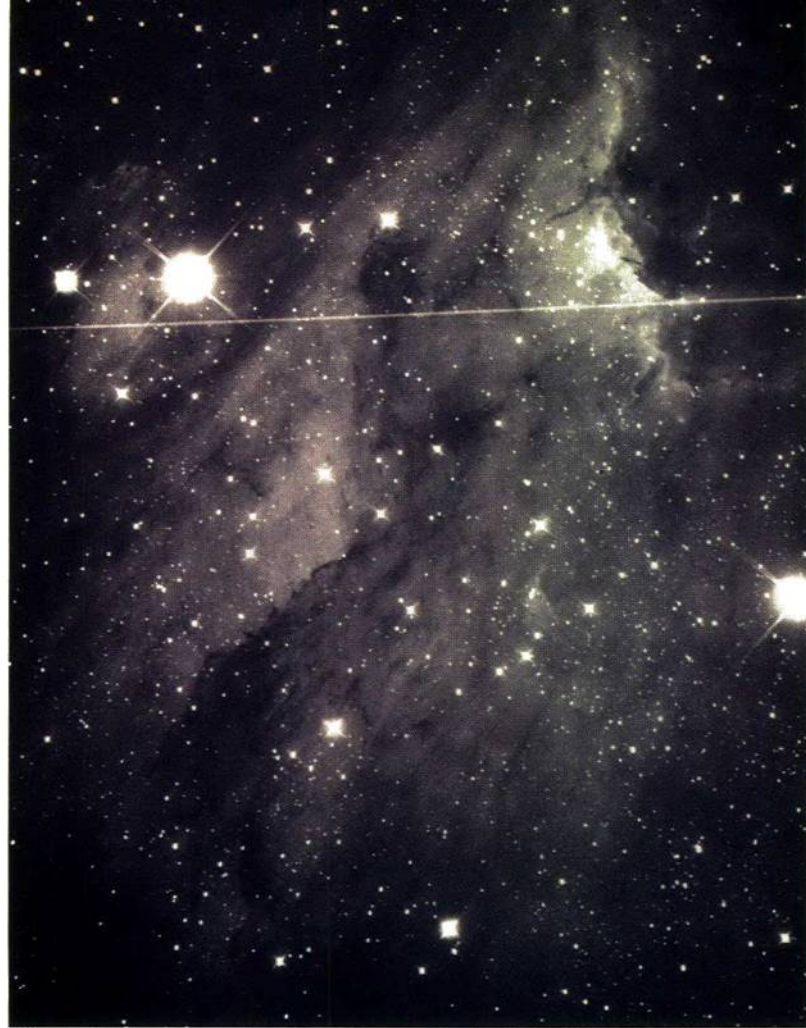
With camera lenses you'd think all you would need to do is set them to infinity and not worry about focus. Usually this works fine. But some lenses may not provide sharp star images when set to infinity. For example, with lenses that attach to your camera with T-rings, the spacing between the lens and camera may be slightly off the optimal distance, shifting the true infinity focus away from the lens' infinity mark. Some of today's new autofocus lenses focus past infinity. In addition, if you use a deep red filter for shooting nebulae on black-and-white films the focus will shift in the direction of the infrared focus point marked on most lenses.

To test the focus of a lens, first mark the lens with an accurate scale — take a piece of masking tape and mark five equal divisions on it, then tape it over the lens' feet scale around the infinity mark. With the camera on the tripod at a reasonably dark site, aim at any group of bright stars. Use an ISO 200 to 400 film and set the aperture to $f/2.8$ to $f/4$. Open the shutter and every minute change the focus on the lens to the next mark. You can use a dim red light to read the focus scale of the camera without fogging the film if you avoid shining the light directly into the lens.

After you've exposed at all five positions, develop the film normally. What you will get is a series of star trails that are stepped in size. The position on the lens that gives the thinnest trail is the position of finest focus. You may need to repeat the test with smaller ranges of focus to refine your setting. Using this method I've found that with a red Lumicon H-alpha pass filter most of my lenses focus at about three-quarters of the way to the infrared focus mark, usually marked by a red dot or scribe line.

Knife-edge Focusing

For deep-sky photography through a telescope, the knife-edge focusing method is by far the most accurate and the most repeatable focus technique available today. To perform a knife-edge test, you place a thin opaque card (a piece of undeveloped film works well) at the focal plane of the telescope. Aim the telescope at a 2nd- or 3rd-magnitude star. Without an eyepiece in place, you'll see a disk of light — that's the out-of-focus star image. Now rock the telescope slightly so that the star beam sweeps directly into the edge of the film chip, our knife edge. If you are inside of focus, the knife edge will cut in from one side of the incoming cone of light — you see a



PERFECT FOCUS and fine-grained Technical Pan film reveal a network of fine dark dust lanes running through the Pelican Nebula in the author's 60-minute exposure with a 12.5-inch $f/5$ Newtonian.

shadow move across the bright disk from one side to the other (see opposite page). If you are outside of focus, the knife edge will cut in from the other side of the light cone — you see the shadow slide in from the other direction.

As you adjust focus, the knife edge will approach the focal point. You'll see the edge's shadow sweep faster and faster across the out-of-focus star. When the knife edge is at the point of exact focus, you will not be able to tell which direction the knife edge is cutting across the beam. The disk will appear to darken suddenly from no particular direction. If you were to put the film at this point, you would get the sharpest focused astrophoto you've ever taken.

A variation on the knife-edge theme is to use a glass plate, known as a Ronchi grating, etched with fine lines on it that act as many small knife edges. The multiple edges make finding the focus star simpler. But just as with a single knife edge, the correct pattern only appears at the point of perfect focus.

The knife-edge method takes all of the guesswork out of focusing deep-sky photos through a telescope. The trick is getting your film to the same focal point as the knife edge. To do that, it's helpful to understand exactly where the film sits in your 35mm camera. If you open the back of your camera you will see the square aperture that contains the curtains of the focal plane shutter. Above and below the shutter aperture are two machined rails to guide the film across the back of the camera. (See the illustration on page 59.) If you look closely you'll discover that the inner set of rails is lower than the outer set — the difference in their height is approximately ten thousandths of an inch (0.01 inch).

The back of the camera contains a spring-mounted pressure plate. This plate rests on the outer rails when the camera back is closed. The film itself runs in front of the pressure plate and between the outer two rails. The film actually hovers above the inner set of rails. (Near the edges of the aperture, the film curves slightly and does sit

HOW TO MAKE A KNIFE-EDGE FOCUSER

If you are looking for a way to focus your shots perfectly every time and do it at low cost, then why not make your own knife-edge focuser? You will need to make two simple focusing aids.

Type 1 Knife-edge Focuser

Use this simple device to set your camera to the exact point of focus at your telescope. To make a Type 1 focuser, cut a plexiglass plate to 1.75 inches square. Next, cut a small black piece of film to 1/2 inch square. One edge of the film chip must be bevel cut with a razor knife by holding it at a slight angle while cutting it. Glue the film chip onto the surface of the plexiglass, slightly off center, and with the bevel-cut edge closest to the center. The bevel should be set with the narrow part glued to the plexiglass. The sharp corner of the beveled film chip forms the knife edge. (If you use Tech Pan film, you should make up a special focuser with a chip of Tech Pan on it because this film is thinner than most other black-and-white and color emulsions.)

Type 2 Knife-edge Focuser

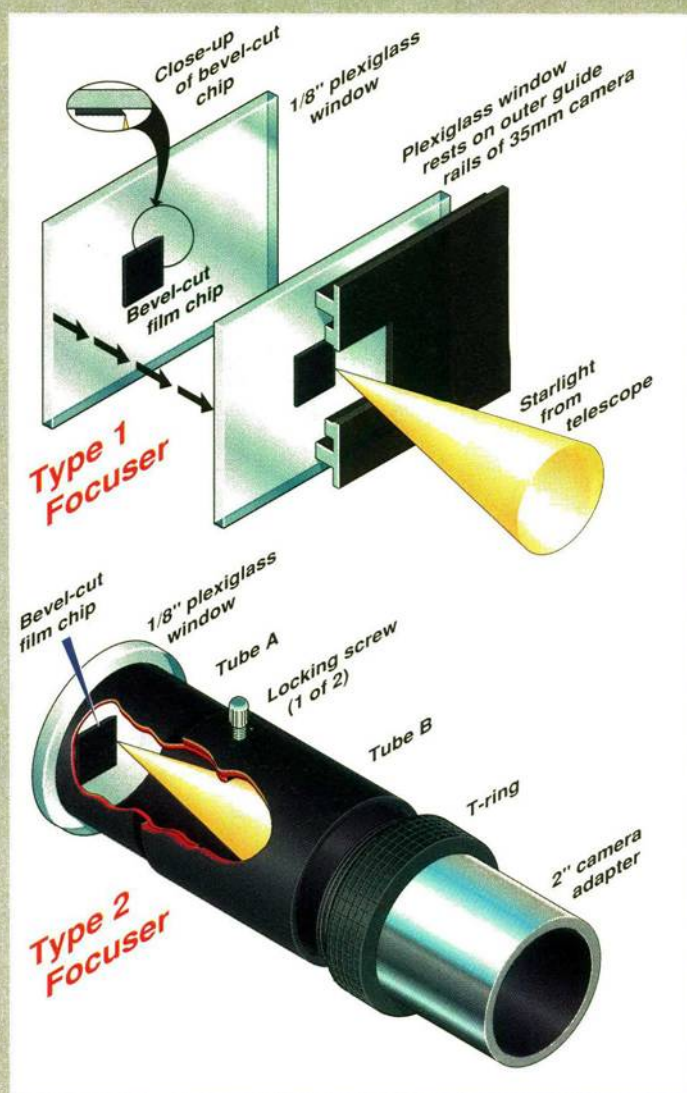
You'll need two short lengths of PVC plastic tubing, sized so that one slides into the other. The larger tube, labeled Tube B, should have a diameter large enough to allow it to rest on the face of the T-ring where your camera would normally go, with the bayonet or thread part of the T-ring covered by the tube.

The total length of the pair of tubes should be adjustable from 1.5 inches to 2 inches. Tube B should have two set screws to hold Tube A firmly in place. To complete your Type 2 focuser, assemble another Type 1 and, using silicone adhesive glue, attach it the end of Tube A with the film chip inward. Set the spacing from the film chip to the front end of Tube B to 1.8 inches initially.

Using Your Homebrew Focuser

Start by centering a 2nd-magnitude star in the field of your telescope. Put your camera (without any film in it) onto your prime-focus camera adapter then open up the back of the camera. Place the Type 1 focuser onto the outer rails of the focal plane aperture with the film chip facing inward toward the telescope. The bevel side should be in the center of the focal plane. Put your eye up to the plexiglass and look past the edge of the film chip into the beam of starlight. As described in the main text, wiggle the telescope and look for the shadow of the knife-edge cutting across the disk of light. Focus until the disk darkens instantly as the telescope is jiggled. The top of the knife-edge film chip, which is sitting exactly where a real piece of film would be, is now precisely at the focal point.

Now very carefully remove the camera body and, without disturbing the telescope's focus in any way, hold the Type 2 focuser



up against the T-ring. Now slide Tube A so that the knife edge it contains will cut the starlight at exactly the same position as the Type 1 did with the camera installed. When you've found the correct position lock down the set screws and check the pattern. Are you still in focus? Then, if you can, lock the focuser on your telescope and double check to see if tightening this screw has shifted focus.

Remove the Type 2 focuser, and attach your loaded camera. It should now be in precise focus. Treat your knife-edge focuser carefully. It is a precisely set instrument and can provide you with countless perfectly focused astrophotos.

on the inner rails, but over most of the aperture the film sits slightly above.) Most films are about 0.007 inch thick, leaving a 0.003-inch gap between the inner rails and front surface of the film. However, Technical

Pan film, a favorite of astrophotographers, is thinner — only 0.005 inch thick — and will sit farther away from the inner guide rails.

So where does the focal plane of the camera lie? Not at the surface of

the pressure plate, nor at the plane of the inner guide rails. Instead, the point of best focus lies below the top surface of the outer guide rails by the thickness of the film. This is a critical bit of knowledge for setting up a

THE GALAXY M33 appears resolved into stars in the author's 60-minute exposure, a demonstration of how much detail amateur astronomers can record in carefully focused astrophotos.

knife-edge focuser — you must set the edge 0.007 inch below the outer rails for using most films. For Tech Pan users, this value becomes 0.005 inch.

Several commercial focusing aids, such as Spectra Astro Systems' SureSharp and Celestron's MFFT accessories, avoid any fuss about measuring focal positions. They come with the knife-edge set in a housing machined with the same back focus distance as your camera body. You place the knife-edge focuser on your camera adapter in place of your camera body, focus, then replace the knife edge with your camera. I've used a SureSharp for years with great success. I would not go back to any other focusing method.

The only drawback is that knife-edge focusers don't work well for eyepiece projection shots of the Moon or planets. You can't focus on an extended object such as a planet. This means you need to swing the scope over to a star, focus, then swing it back to the planet. But at the high powers used in eyepiece projection photography, finding a focus star then refinding the target planet can be difficult. Using a fine ground glass screen and a focus magnifier may still be the best route for focusing planetary shots.

Where to Focus

No rundown on focusing would be complete without discussing the best place in the field to focus the star. At first glance it might appear that anywhere in the field is suitable. For moderate speed (f/6 to f/8) Newtonians and f/8 or slower refractors, the center of the field is a good choice because the field is relatively flat over the 35mm frame. If a star in the center of the frame is in focus, a star at the edge will also be sharp.

But fast f/4 or f/5 Newtonians, some fast refractors, and many Schmidt-Cassegrain telescopes have curved focal planes — focus for the center, and the edge will be blurry. For these systems, place your focus star halfway from the center of the camera's field to the edge on the short dimension of the film frame, or one-third of the way from the center along the long dimension. Because the curved focal plane will not allow all of the stars in the field to be in focus at once, the best compromise is



to place the point of best focus at one of these locations. The final photo will appear reasonably sharp across the entire frame despite the fact that the center of the field and edges are not in perfect focus.

Checking Your Results

Once you have your final photos, you will want to check how well you did with the focusing. There are several ways to measure the sizes of the smallest stars on your negatives. The easiest way is to make an 8x10 print of the negative and, using a 10x magnifier and either a pair of machinist's calipers or a graphic arts comparator scale, measure the size of the dimmest star on the print. An acceptable size on the print is between 0.01 and 0.02 inch. Measure a number of dim stars and average your results.

Another way is to mount up the negative in a slide mount for projection — or if you use slide film you are all set. Project the image onto a distant wall. Measure the height of the projected image. Knowing that the small dimension of most slide mounts is about 0.91 inch you can calculate how much the image has

been scaled up by projection. Use a ruler to measure the minimum star diameters off the wall and then scale them down to find the size on the negative or slide itself. Again, an actual size of less than 0.003 inch is excellent and something to be proud of.

Getting one such sharp astrophoto per night used to be a real accomplishment. But using these techniques will spoil you. Not only will your photos come back with pinpoint star images, but the number of perfect shots you'll be able to get every night will go way up. No longer will you have to waste precious nights reshooting the same objects over and over because of poor focus. Getting a sharp and clear focus should be a simple and routine procedure. Once you learn the fine art of focusing, you'll wonder how you ever got along without it. □

Chris Schur, who lives in Payson, Arizona, is a leading astrophotographer. His images appear regularly in ASTRONOMY and his last feature article was "Fieldtesting Kodak's Ektar Films" (September 1991).

A crystal-clear blue sky greets you as you leave work. You hurry home, turn on the early evening report, and hear the good news: The weather's supposed to hold for the rest of the night. After a quick supper, you set up your telescope and wait for darkness to fall. Maybe tonight you'll see those elusive dark markings on Mars, and surely the Great Red Spot on Jupiter will be visible.

You slip in a medium-power eyepiece and gaze through the scope, only to feel your hopes turn to despair. Mars shows some dark markings, but what are they? Is that big dark patch Syrtis Major or Solis Lacus or perhaps even Meridiani Sinus? And on Jupiter the Great Red Spot is nowhere to be found, despite the intricate detail you see in the planet's belts and zones. Deep down you feel as though you're missing something important. There's got to be a better way to study the planets.

There is. The reason you can't identify the features on Mars or see the Red Spot every time you look at Jupiter is that the planets rotate. The view you get of any planet changes continuously throughout the night and from one night to the next. The key to pinpointing features on the surface of a planet is to know what side of the planet faces in your direction as you're observing.

The easiest way to do this is to have a personal computer do the tedious calculations. That's what the two programs presented here will do. One calculates the central meridian on Mars — the longitude that runs through the center of the Martian disk — for any time you might be observing. The other calculates the time when the Great Red Spot transits the Jovian disk. The programs are written in GW-BASIC, but should be easily adaptable to other versions of BASIC.

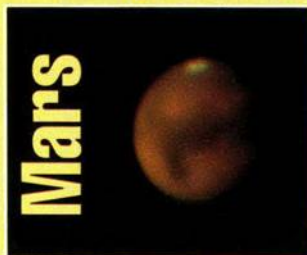
The View of Mars

The first program, called MARS.BAS, calculates the central meridian on Mars at any specified time. Once you've entered the program and type RUN, all you need to supply is the date and time you plan to observe; the program does the rest.

Luckily astronomers have been observing Mars for centuries, so they know exactly how long it takes to rotate once on its axis — 24 hours 37 minutes and 22.66 seconds. To find the central meridian at any time, the

ASTRONOMICAL COMPUTING

Computing



Donald C. Parker

&



Charles Capen

What's visible on Mars tonight? When will Jupiter's Red Spot come into view? Let your personal computer give you the answers.

by Richard Talcott

program first calculates the positions of Mars and Earth and then where the prime meridian lies relative to the center of Mars' disk. The program gives values precise to the nearest degree, which is plenty accurate for anyone viewing Mars in a telescope.

As an example, suppose you want to observe Mars on the evening of July 20, 1993. If you live in mid-northern latitudes (between about 30° and 45° north), the sky becomes reasonably dark by around 9 p.m. local daylight time, or 21 hours in 24-hour mode. When you type RUN, the program asks for the year, month, day, and time you plan to observe. Enter 1993 for the year, 7 for the month, 20 for the day, and 21 for the hour. The program then prints the central meridian at that time — 293°.

That puts Syrtis Major near the center of the Martian disk you'll see in your telescope. Because Mars rotates at just under 15° per hour, within two hours Syrtis Major will be

halfway between the center and limb of Mars, while Meridiani Sinus comes into view on the opposite side. To know what it is you're seeing, you'll want a map of Mars that shows the major features as well as their longitudes. (See page 78 of the November 1992 issue.)

To have the program accept and print out local times, you must initially define your time zone as described in the opening REMark statements. If you prefer your input and output to be in universal time, the unambiguous system of time reckoning used by astronomers around the world, set ZONE = 0.

Spotting the Red Spot

The program for calculating the transit time of Jupiter's Great Red Spot, called JUPITER.BAS, works opposite to the program for Mars. Instead of entering a time and getting out the longitude of the central meridian, you start with the longitude of the Red Spot and get out the time it is at the center of Jupiter's disk.

Unfortunately, Jupiter's rotation is more complex than that of Mars. Unlike Mars, which is a solid body and thus has one rotation rate for the entire planet, Jupiter's "surface" is actually a thick layer of clouds that rotates at different rates. The Great Red Spot lies in the planet's South Equatorial Belt, which rotates around Jupiter once every 9 hours 55 minutes and 41 seconds. Adding to the complexity, the Great Red Spot wanders up to several degrees in longitude. It is currently located at about 35° longitude, the value the program uses, but it pays to keep abreast of any changes. (ASTRONOMY's monthly column Through the Eyepiece occasionally updates the Red Spot's location.)

Once you've loaded the program, type RUN and JUPITER.BAS will ask you for the year, month, and day you are interested in. The program will give you the local times in 24-hour mode when the Red Spot transits. You will get two or three different times, because Jupiter's rapid rotation brings the Red Spot into view more than once every day.

For instance, suppose you plan to observe Jupiter after you finish with Mars on July 20. Enter 1993 for the year, 7 for the month, and 20 for the day. The program will then print out the transit times — 2:11, 12:07, and 22:03 central daylight time. Jupiter rotates faster than any other planet,

Mars

```

10 REM This program calculates the central meridian on Mars for any time.
20 REM Enter your time zone in line 60. Set zone to 4 if you are on EDT,
30 REM 5 if CDT, 6 if MDT, and 7 if PDT. Add one hour more for standard time.
40 REM On line 100, express hours in 24-hour mode (e.g. 10:30 p.m. = 22.5).
50 DEFDBL A-Z
60 ZONE=5
70 INPUT "Enter the year of observation ";YEAR
80 INPUT "Enter the month ";MONTH
90 INPUT "Enter the day ";DAY
100 INPUT "Enter the hour (in 24-hour mode) ";HOUR
110 DAY=DAY+(HOUR+ZONE)/24+1/1440
120 IF MONTH<3 THEN YEAR=YEAR-1:MONTH=MONTH+12
130 A=INT(YEAR/100):B=2-A+INT(A/4)
140 JD=INT(365.25*YEAR)+INT(30.6001*(MONTH+1))+DAY+1720994.5#+B
150 DAYS=JD-2451545:CEN=DAYS/36525
160 RTD=57.29578
200 REM Calculate orbit of Mars
210 PP=1.88075126#PI=1.85061-25.47/3600*CEN
220 PE=9.341233E-02+1.1902E-04*CEN:PA=1.52366231#-7.221E-05*CEN
230 PO=49.57854-1020.19/3600*CEN:PW=336.04084#+1560.78/3600*CEN
240 PL=355.45332#+524033*PI
250 MEAN=PL-PW:Z=MEAN/360:MEAN=MEAN-360*INT(Z)
260 TRUE=MEAN+360/3.14159265359#*PE*SIN(MEAN/RTD)
270 Z=TRUE/360:TRUE=TRUE-360*INT(Z)
280 L=TRUE+PW
290 R=PA*(1-PE*PE)/(1+PE*COS(TRUE/RTD))
300 SINPSI=SIN((L-PO)/RTD)*SIN(PI/RTD)
310 PSI=ATN(SINPSI/SQR(1-SINPSI*SINPSI))
320 NUM=SIN((L-PO)/RTD)*COS(PI/RTD)
330 DEN=COS((L-PO)/RTD)
340 LP=ATN(NUM/DEN)*RTD+PO
350 IF DEN<0 THEN LP=LP+180
360 RP=R*COS(PSI)
400 REM Calculate Earth's orbit
410 EE=1.671022E-02-3.804E-05*CEN:EA=1.00000011#-5E-08*CEN
420 EW=102.94719#+1198.28/3600*CEN:EL=100.46435#+.9856091*PI
430 OBL=23.43928
440 MEANE=EL-EW:Z=MEANE/360:MEANE=MEANE-360*INT(Z)
450 TRUEE=MEANE+360/3.14159265359#*EE*SIN(MEANE/RTD)
460 Z=TRUEE/360:TRUEE=TRUEE-360*INT(Z)
470 LE=TRUEE+EW
480 RE=EA*(1-EE*EE)/(1+EE*COS(TRUEE/RTD))
490 LAMB=ATN(RE*SIN((LP-LE)/RTD)/(RP-RE*COS((LP-LE)/RTD)))*RTD+LP
500 BETA=ATN(RP*TAN(PSI)*SIN((LAMB-LP)/RTD)/(RE*
SIN((LP-LE)/RTD)))*RTD
600 REM Determine Mars' position
610 NUM=SIN(LAMB/RTD)*COS(OBL/RTD)-TAN(BETA/RTD)*SIN(OBL/RTD)
620 DEN=COS(LAMB/RTD)
630 RA=ATN(NUM/DEN)*RTD
640 IF NUM<0 THEN RA=RA+180
650 IF NUM<0 THEN RA=RA+180
660 SINDEC=SIN(BETA/RTD)*COS(OBL/RTD)+
COS(BETA/RTD)*SIN(OBL/RTD)*SIN(LAMB/RTD)
670 DEC=ATN(SINDEC/SQR(1-SINDEC*SINDEC))*RTD
680 DSQRD=RE*RE+R-R-2*RE*R*COS((L-LE)/RTD)
690 DIST=SQR(DSQRD)
800 REM Compute central meridian on Mars
810 AO=317.681-108*CEN:DO=52.886-.061*CEN
820 WO=176.868+350.891983#*DAYS:Z=WO/360:WO=WO-360*INT(Z)
830 W1=W0-350.891983#*.0057755*DIST
840 SINB=SIN(DO/RTD)*SIN(DEC/RTD)-
COS(DO/RTD)*COS(DEC/RTD)*COS((AO-RA)/RTD)
850 COSB=SQR(1-SINB*SINB)
860 SINK=(SIN(DO/RTD)*COS(DEC/RTD)*COS((AO-RA)/RTD)-
COS(DO/RTD)*SIN(DEC/RTD))/COSB
870 COSK=COS(DEC/RTD)*SIN((AO-RA)/RTD)/COSB
880 K=ATN(SINK/COSK)*RTD
890 MER=W1-K:IF COSK<0 THEN MER=MER+180
900 IF MER>360 THEN MER=MER-360
910 PRINT:PRINT "The central meridian on Mars is ";USING"###";MER
920 END

```

Jupiter

```

10 REM This program computes the transit times of the Red Spot for any date.
20 REM Enter your time zone in line 50. Set zone to 4 if you are on EDT,
30 REM 5 if CDT, 6 if MDT, and 7 if PDT. Add one hour more for standard time.
40 DEFDBL A-Z
50 ZONE=5
60 INPUT "Enter the year of observation ";YEAR
70 INPUT "Enter the month ";MONTH
80 INPUT "Enter the day ";DAY:DAY=DAY+ZONE/24+1/1440
90 IF MONTH<3 THEN YEAR=YEAR-1:MONTH=MONTH+12
100 A=INT(YEAR/100):B=2-A+INT(A/4)
110 JD=INT(365.25*YEAR)+INT(30.6001*(MONTH+1))+DAY+1720994.5#+B
120 DAYS=JD-2451545:CEN=DAYS/36525
130 RTD=57.29578
200 REM Calculate orbit of Jupiter
210 PP=11.8567785#PI=1.3053-4.15/3600*CEN
220 PE=4.839266E-02-.0001288*CEN:PA=5.20336301#+6.0737E-04*CEN
230 PO=100.55615#+1217.17/3600*CEN:PW=14.75385+839.93/3600*CEN
240 PL=34.40438+.083086762#*PI
250 MEAN=PL-PW:Z=MEAN/360:MEAN=MEAN-360*INT(Z)
260 TRUE=MEAN+360/3.14159265359#*PE*SIN(MEAN/RTD)
270 Z=TRUE/360:TRUE=TRUE-360*INT(Z)
280 L=TRUE+PW:R=PA*(1-PE*PE)/(1+PE*COS(TRUE/RTD))
290 SINPSI=SIN((L-PO)/RTD)*SIN(PI/RTD)
300 PSI=ATN(SINPSI/SQR(1-SINPSI*SINPSI))
310 NUM=SIN((L-PO)/RTD)*COS(PI/RTD):DEN=COS((L-PO)/RTD)
320 LP=ATN(NUM/DEN)*RTD+PO:IF DEN<0 THEN LP=LP+180
330 RP=R*COS(PSI)
400 REM Calculate Earth's orbit
410 EE=1.671022E-02-3.804E-05*CEN:EA=1.00000011#-5E-08*CEN
420 EW=102.94719#+1198.28/3600*CEN:EL=100.46435#+.9856091*PI
430 OBL=23.43928
440 MEANE=EL-EW:Z=MEANE/360:MEANE=MEANE-360*INT(Z)
450 TRUEE=MEANE+360/3.14159265359#*EE*SIN(MEANE/RTD)
460 Z=TRUEE/360:TRUEE=TRUEE-360*INT(Z)
470 LE=TRUEE+EW
480 RE=EA*(1-EE*EE)/(1+EE*COS(TRUEE/RTD))
490 LAMB=ATN(RE*SIN((LP-LE)/RTD)/(RP-RE*COS((LP-LE)/RTD)))*RTD+LP
490 BETA=ATN(RP*TAN(PSI)*SIN((LAMB-LP)/RTD)/(RE*
SIN((LP-LE)/RTD)))*RTD
600 REM Determine Jupiter's position
610 NUM=SIN(LAMB/RTD)*COS(OBL/RTD)-TAN(BETA/RTD)*SIN(OBL/RTD)
620 DEN=COS(LAMB/RTD)
630 RA=ATN(NUM/DEN)*RTD:IF NUM<0 THEN RA=RA+180
640 IF NUM<0 THEN RA=RA+180
650 SINDEC=SIN(BETA/RTD)*COS(OBL/RTD)+
COS(BETA/RTD)*SIN(OBL/RTD)*SIN(LAMB/RTD)
660 DEC=ATN(SINDEC/SQR(1-SINDEC*SINDEC))*RTD
670 DSQRD=RE*RE+R-R-2*RE*R*COS((L-LE)/RTD):DIST=SQR(DSQRD)
800 REM Compute central meridian on Jupiter at midnight
810 AO=268.05-8.999999E-03*CEN:DO=64.49+.003*CEN
820 WO=43.3+870.27*PI:Z=WO/360:WO=WO-360*INT(Z)
830 W1=W0-870.27*PI
840 SINB=SIN(DO/RTD)*SIN(DEC/RTD)-
COS(DO/RTD)*COS(DEC/RTD)*COS((AO-RA)/RTD)
850 COSB=SQR(1-SINB*SINB)
860 SINK=(SIN(DO/RTD)*COS(DEC/RTD)*COS((AO-RA)/RTD)-
COS(DO/RTD)*SIN(DEC/RTD))/COSB
870 COSK=COS(DEC/RTD)*SIN((AO-RA)/RTD)/COSB
880 K=ATN(SINK/COSK)*RTD
890 MER=W1-K:IF COSK<0 THEN MER=MER+180
900 IF MER>360 THEN MER=MER-360
1000 REM Calculate transit times of Red Spot
1010 REM Line 1020 defines current longitude of the Red Spot
1020 RED=35
1030 DIFF=RED-MER:IF DIFF<0 THEN DIFF=DIFF+360
1040 WHILE DIFF<870.27
1050 TRAN=DIFF/870.27*24:H=FIX(TRAN):M=FIX(60*(TRAN-H))
1060 PRINT:PRINT "The Red Spot transits the Jovian meridian at";
1070 PRINT USING"###.##";H:PRINT USING"###.##";M
1080 DIFF=DIFF+360
1090 WEND
1100 END

```

over 36° per hour, so you need to observe within two hours of the meridian crossing to see the Red Spot at all.

One simple change can make these programs more powerful by letting you avoid entering the year, month, and day every time you run them. Just declare these values as constants in the opening lines of the program (e.g. replace line 70 of MARS.BAS with YEAR = 1993). This

will prove particularly helpful if you plan on observing the planets for several hours on one night or for several nights in a row.

You now have the tools to make your planetary observing more rewarding. No more jumble of nameless dark markings on Mars. No more wondering where the Great Red Spot is hiding. As long as you've got a personal computer and the BASIC pro-

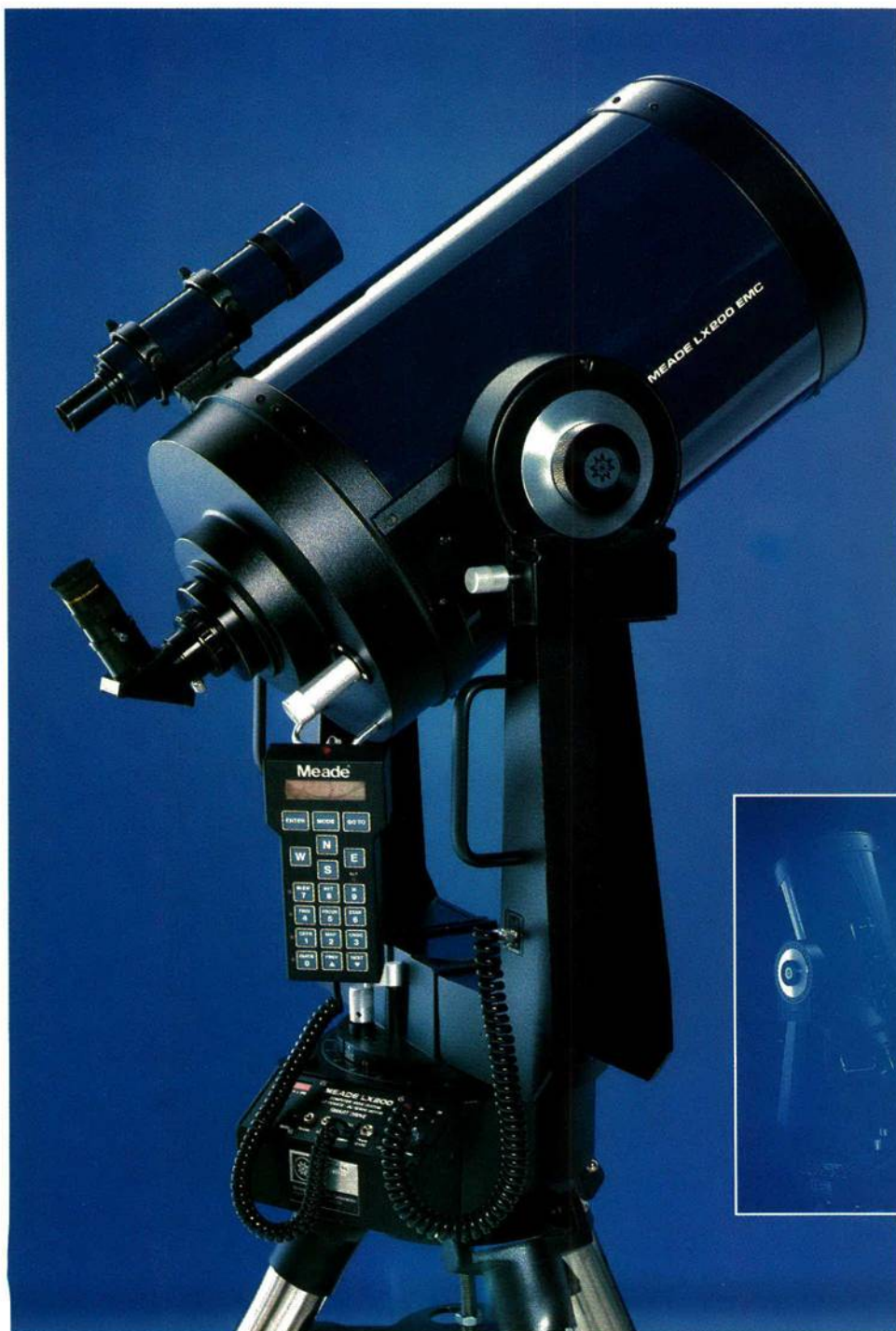
gramming language, you can use MARS.BAS and JUPITER.BAS to show you what you can see and when. □

If you don't want to enter these programs by hand but still want to use them, send one diskette and a self-addressed, postage-paid diskette mailer to ASTRONOMY and we'll copy the programs for you.

Using Meade's LX200

We took one of Meade's new LX200 Schmidt-Cassegrains out for a computer-guided tour of the sky.

by Alan Dyer



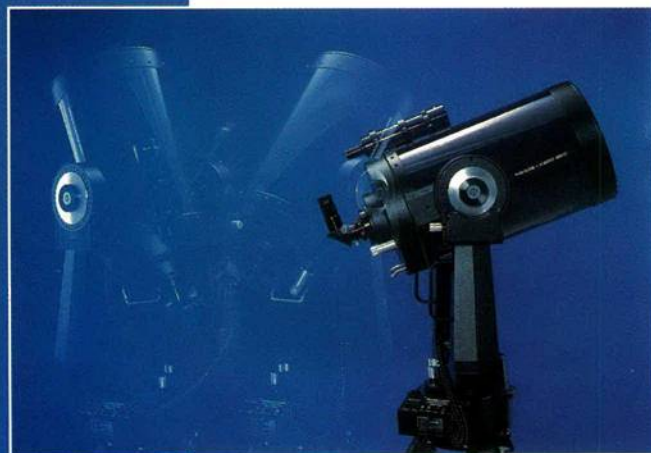
One of the fundamentals of using any telescope is learning where in the sky to point it to find some elusive target. Another task that many beginners find intimidating is polar aligning an equatorial mount. It's really a simple procedure but the process can seem confusing.

Finding objects and polar alignment — these two phobias haunt many backyard astronomers. Now, Meade's new LX200 series addresses both those fears with telescopes that combine the portability and versatility of Schmidt-Cassegrain optics with a sophisticated computer-driven mount.

So what is it like to use this computerized telescope? I took a 10-inch LX200 out for a spin around the universe and found that it worked very well.

A New Style of Mount

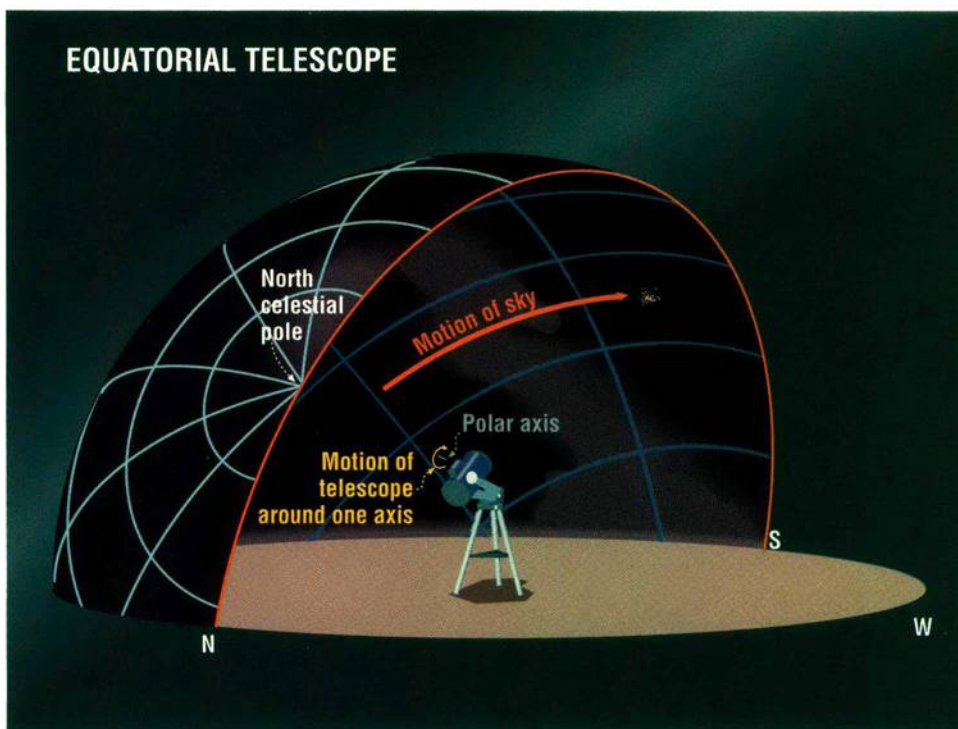
The LX200 series of Schmidt-Cassegrains includes 8- and 10-inch telescopes, both of which are available in a choice of focal ratios. The f/10 models are suitable for general-purpose observing while the f/6.3



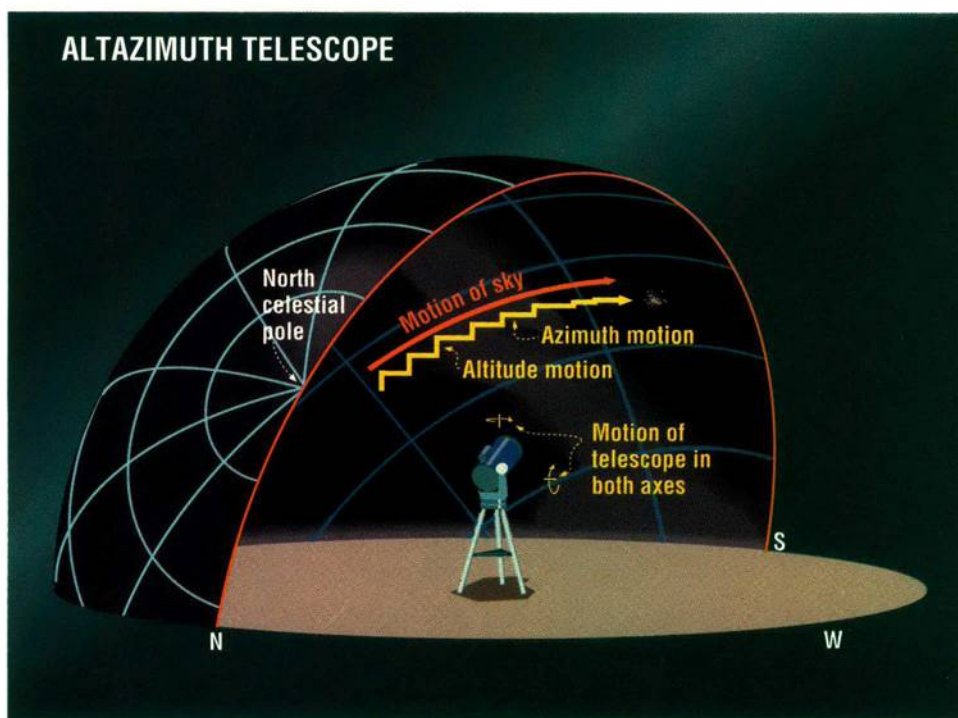
FOLLOWING OBJECTS from east to west across the sky in the altazimuth mode requires that the telescope move both horizontally and vertically.



WHEN SET UP AS AN EQUATORIAL telescope, the LX200, like all Schmidt-Cassegrains, is placed on a tilted wedge that aims the telescope's polar axis at the celestial pole. The scope can then follow the rotating sky by turning around one axis.



AN ALTAZIMUTH TELESCOPE requires continually adjusting two axes to track objects. When set up in this manner, the LX200's computer pulses the motors at speeds that vary depending on where in the sky the telescope is aimed.



versions are better suited to deep-sky photography. All the telescopes share the same computerized-drive technology.

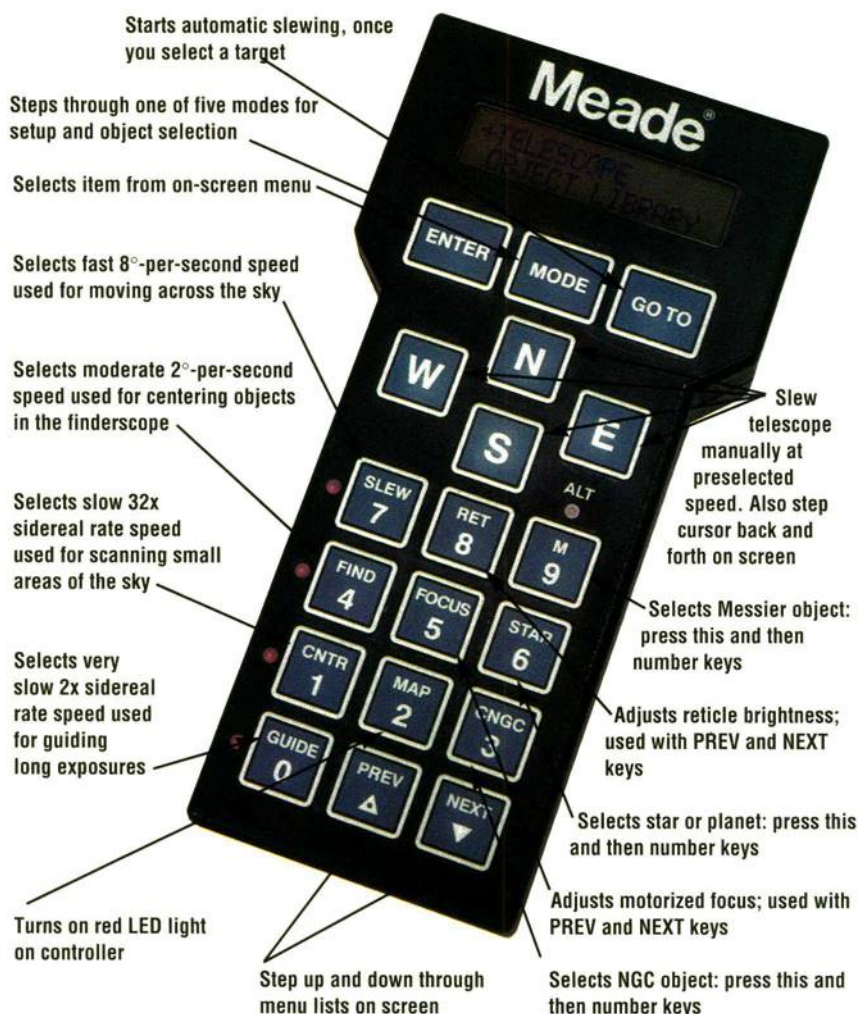
The most innovative feature is the LX200's ability to track objects without the need for polar alignment or even the need for an equatorial mount, a first for a commercially made amateur telescope.

Traditionally, telescopes come with either of two types of mounts: an altazimuth or an equatorial. The alt-

azimuth mount is the less expensive of the two. It swings through two directions: up and down (the altitude motion) and side-to-side (the azimuth motion). However, objects in the sky aren't so obliging — they do not move straight up and down (unless you live at the equator) nor do they move only side-to-side parallel to the horizon (unless you live at the South Pole). Instead, objects rise in the east at an angle to the horizon and move across the sky in sweeping arcs. Fol-

lowing an object with an altazimuth mount requires nudging the scope first a little up, then a bit to the side, a little farther up, more to the side, and so on through the night.

Continually jockeying the telescope through two motions is an inconvenience. Wouldn't it be nice to have the telescope automatically follow the object for you? That's what an equatorial mount does. Though equatorial mounts differ in design, all have two axes of motion, just like



THE HAND CONTROLLER for the LX200 is logically laid out and simple to operate, even at night and with gloves on. The display illumination can be dimmed or turned off completely.

an altazimuth. But with an equatorial, the mount is tilted so that one axis of rotation is aimed toward the pole of the sky, the point around which all the stars appear to revolve. In the Northern Hemisphere, this requires that the so-called "polar axis" of the mount be aimed close to Polaris, the North Star. With the telescope and sky both rotating about the same pivot point, the telescope can now follow any celestial object for hours simply by rotating around one axis at one set speed.

Attach a drive motor to the axis and you have a telescope capable of tracking objects unattended. Objects that would otherwise quickly drift out of the field due to the sky's apparent motion now appear perfectly stationary in the eyepiece.

But equatorial mounts for large telescopes can get big and bulky, requiring heavy counterweights, heavy-duty wedges, and generally massive designs to counteract the flexure otherwise introduced by tilting the mount to aim at the celestial pole.

Now modern technology makes another option possible — an altazimuth mount, but one with a difference. Each axis is driven by a stepper motor that in turn is controlled by a computer. The high-tech motors ap-



THE CONTROL PANEL located on the base of the telescope contains plugs for the power supply, hand controller, and declination motor — the three standard items — plus plugs for optional accessories such as auto-guiders and focusing motors.

ply the right amount of altitude and azimuth movement in concert to keep an object centered. The speed of the altitude and azimuth motions vary depending on where in the sky the telescope is aimed. But the computer knows where the telescope points and instantly performs the calculations to pulse the motors at the right speed. The Meade LX200 Schmidt-Cassegrains are the first commercial hobbyist telescopes to employ this style of computerized altazimuth mount.

Your Choice — Altazimuth or Polar

Of course, there is a catch. As an altazimuth telescope tracks a target across the sky, the field of view slowly rotates. For viewing through an eyepiece this is no problem. But having the field rotate at the focus of a camera during long exposures would cause all the stars to trail in circles. One way around this is to slowly rotate the camera in the same direction to compensate for the field rotation. This is feasible but adds a new level of technical complexity.

In the case of the LX200, the solution is much simpler. If you wish to do long-exposure deep-sky photography, you can purchase the optional equatorial wedge and polar align as you would any other Schmidt-Cassegrain telescope. Although in the case of the LX200 the computer's "polar" mode provides electronic assistance — to polar align, the computer steps you through a routine of aiming at Polaris and then at a bright star elsewhere in the sky. Or you can use more traditional eyeball methods for aiming the polar axis at the celestial pole.

But polar aligning with either technique is necessary only for deep-sky photography. For short exposures of the Moon and for visual observing, the altazimuth mode is fine. That's why an equatorial wedge does not come as standard equipment with any of the LX200 models.

Setting Up the Telescope

For my computerized nights under the stars, I set up the LX200 in the altazimuth mode, likely to be one most users prefer. Before heading out into the night, I first had to program the LX200 with some vital statistics. It must know the latitude and longitude of the observing site, accurate to the nearest arcminute if possible. This information can be gleaned from a road atlas or topographic map.

The computer also needs to know the time, the time zone, and the date. This initialization took about

an hour, most of which was spent carefully reading the manual. The procedure needs to be done only once. Powered by a long-life lithium battery, the telescope's computer maintains a memory of the locations of up to four observing sites and keeps track of the date and time.

A minor oversight in the otherwise thorough 100-page manual is that the instructions for inputting the date do not tell you that you need to use the American convention of month/day/year. Owners living elsewhere who use the day/month/year convention may find this confusing at first. Input the wrong date and the LX200's planet positions will all be wrong.

The next step was assembling the telescope. This required bolting the base of the telescope directly to the top of the tripod. Lifting the 61-pound telescope (in the case of the 10-inch model) onto the tripod and then carefully centering its bolt hole

over the bolt sticking up from the tripod is a task guaranteed to build arm muscles and create a few anxious moments. But once the telescope was secured to the tripod, I discovered one of the wonderful benefits of the altaz setup — it's solid.

When they are tilted on an equatorial wedge, fork-mounted scopes have always exhibited some degree of bounce and vibration. It's an outcome of taking that much mass and tipping it at an angle. But with the telescope firmly centered over the tripod, the 10-inch LX200 was rock steady. The scope hardly budged even under gusty wind conditions. After a firm rap to the side of the tube, what vibration there was died out in less than a second.

Once assembled, the main task was leveling the telescope by adjusting the height of the tripod legs. I then aimed the telescope at a known alignment star. (You do need to be

READY . . .

→TELESCOPE
OBJECT LIBRARY

After turning on the scope, select TELESCOPE from the menu.

→1)SITE
2)ALIGN

The display then indicates SITE and ALIGN. Select SITE.

→1)HOM ✓
2)JTR

Select one of four observing sites you can name with a three-letter code.

LAT = +42° 51'
LONG = 088° 30'

Type in the latitude and longitude of your site.

→LOCAL=14:14:53
SIDE = 01:03:22

Then switch to the time display. Type in the correct time.

Hours from GMT:
+06

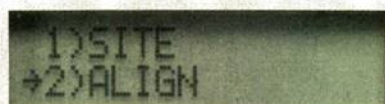
Enter your time zone by typing in hours east or west of Greenwich Time.

DATE = 03/02/93

Enter the correct date. The telescope then calculates current planet positions.

THE INITIAL PROGRAMMING of the LX200 requires typing in your latitude and longitude, current time, time zone, and date. You can input the particulars for up to four favorite observing sites.

SET . . .



Select ALIGN from the SITE/ALIGN menu.



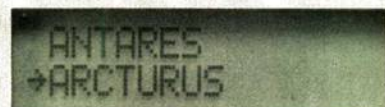
Select ALTAZ if you are setting up without the equatorial wedge.



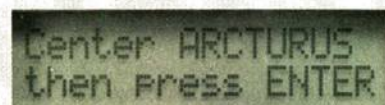
Level the telescope as accurately as you can and then press ENTER.



Select an alignment star when the telescope prompts you.



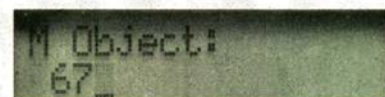
Press ENTER to reveal a list of 33 bright stars. Select one.



Center this star in the telescope's eyepiece and then press ENTER.

SETTING UP EACH NIGHT in the altazimuth mode requires precisely leveling the telescope and then aiming at a known star. You're now set to search for celestial objects.

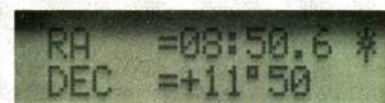
OBSERVE . . .



To find Messier 67, hit the M button, type 6 and then 7.



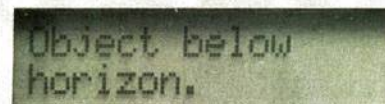
The display then indicates the object's visual rating, type, magnitude, and size.



Press ENTER to bring up the object's coordinates.



Press GOTO to slew the telescope. A dual bar graph counts down as both axes move.



But if the object is below the horizon, the computer tells you so.

FINDING A TARGET OBJECT simply requires typing in its catalog number and then pressing GOTO. You can also find an object by typing in its coordinates.

able to identify a few bright stars — don't expect the telescope to do all the work for you!) The LX200 then began to track in the altazimuth mode.

The LX200 tracked objects without a hitch. Even following an object through the zenith, where the telescope has to perform a rapid about-face from east to west, proved to be no problem — after several hours, objects were still well within the $1/2^\circ$ field of the standard 26mm eyepiece.

Finding Your Way among the Stars

The same computer and motors that provide the altazimuth tracking capability also give the LX200 the ability to find objects at the touch of a button. To locate M42 you simply punch up M, 4, 2, ENTER and GOTO, and away the telescope slews at 8° per second. When it reaches the target it quickly stops and then backtracks slightly to compensate for a slight overshoot.

The LX200 knows the current position of all the planets, including Pluto. I tried it out on Mars and the LX200 located the planet just fine. In fact, when slewing all around the sky, I found that each object, be it planet or deep-sky object, almost always ended up within the field of the 26mm eyepiece, sometimes off center by an acceptable 10 arcminutes or less but often dead center. The worst cases seemed to be objects located near the celestial pole, where targets such as M81 and M82 would be off by 15 to 20 arcminutes, placing them just outside the field of the 26mm eyepiece. The manual does caution users that close to the pole, where the lines of right ascension converge, the LX200's encoders "can yield ambiguous data." But for targets around the rest of the sky the pointing ability of the LX200 was impressive.

Achieving a high degree of pointing accuracy does require that the telescope be exactly level. The circular bubble level supplied on the base of the telescope proved not up to the task. A small carpenter's level placed on the base under the fork arms gave better results — target objects ended up consistently closer to the center of the field.

Slewing back and forth between two widely separated objects always brought the objects back to precisely the same positions in the field. This indicated there was no loss of position data, no mistracking of the encoders, no mechanical slippage, nothing that would cause the LX200 to accumulate position errors. Any

error in locating an object seemed to be due only to initial setup errors (an off-level telescope, for example).

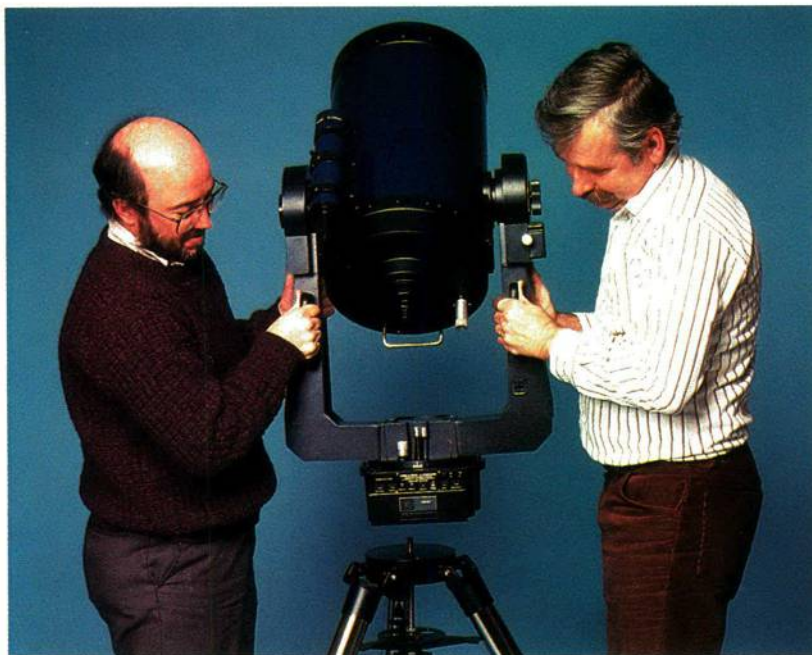
If your goal is to add a computer and a CCD camera to an LX200 to create a remote-controlled telescope, you might want to select an f/6.3 model telescope. The wider field of view of the faster telescope would be more forgiving of minor pointing errors and is better for imaging many types of deep-sky objects anyway.

For the LX200 to keep track of where it is pointed, you must always move the telescope by using a GOTO command or by slewing it with the hand-controller buttons. Re-aiming the telescope by unlocking the axes and manually swinging the mount causes the LX200 to "lose sync" with the sky. This never proved to be a limitation. However, optional encoders are available that allow the scope to keep track of its position no matter how it is moved.

In addition to calling up individual Messier or NGC (New General Catalogue) objects by catalog number, you can also use the keypad to step through objects in the database, simply allowing the scope to show you whatever object comes next. When I stepped through the database in this manner, the telescope always kept to the same area of the sky, with no wild excursions far to the north or south. This is because objects in the computerized version of the NGC database, the CNGC, are not ordered simply from west to east by right ascension (as they are in the original catalog) but are grouped together in bands of declination as well, a very useful feature for computerized object hunting.

The telescope is also smart enough to avoid becoming tangled in its own cords. When swinging from the northeast to northwest and back again, for example, the telescope always retraced its steps, even if it meant taking the long way around. This prevents the LX200 from winding up its declination cable, which runs from the fixed control panel to one of the moving fork arms.

To locate a star or planet, you input a code number you need to look up in the telescope's manual. For example, the star Arcturus is number 147 out of 351 stars. Planets are given easy-to-remember numbers: Mercury is 901, Venus 902, Mars 904, Jupiter 905, and so on. When you punch in 904, the screen returns by displaying the word MARS and its current coordinates. When you punch up a star number, however, you don't get the helpful confirmation of the star's name appearing in the display.



THE 10-INCH VERSION of the LX200 (shown here) weighs a hefty 61 pounds, an important factor to consider if you will be setting up this telescope by yourself. Select the 37-pound 8-inch model if portability and ease of handling are priorities.

For future editions of the software, it would also be nice to be able to step through just the Messier objects. When stepping through the database one object at a time, the objects are labeled only by their CNGC numbers.

My computerized evenings of viewing took place on some winter nights with temperatures well below freezing. The telescope worked without complaint. The liquid crystal display on the hand controller worked fine in temperatures down to 20° F or so but started to become faint and difficult to read at 10° F and below.

Features and Then Some

The LX200 offers a number of special features. For visual observing the most useful is the ability to tell the computer to show you only a select number of objects. You can have it find only objects brighter than a certain magnitude, larger than a certain size, higher than a certain altitude, or of a specified type — just galaxies for example. A handy feature is the visual quality rating assigned to every object, a 7-point scale from Super to Very Poor. If you want to look only at the sky's best sights, for example, you can tell the computer to show you just objects with ratings better than, say, Very Good.

For astrophotography there is also a built-in timer for clocking exposures. You can use the keypad to adjust the drive speed to match solar, lunar, and planetary motions. The clock drive also comes equipped with a periodic-error-

correction circuit called Smart Drive. This electronically compensates for predictable speed variations introduced by drive-gear errors, a feature useful for deep-sky photography.

One of the benefits of a software-based drive system such as the LX200's is that it can be updated and upgraded. Users can add a \$99 chip that expands the standard database from 747 objects to almost 8,000. In the future, perhaps we'll see features such as the ability to input a comet's orbital elements or positions and have the telescope automatically track the comet, as well as programmed guided tours of the sky.

But during my use of the LX200 I discovered the biggest benefit of using a computerized telescope is one never touted in the ads or literature — it makes observing a much more comfortable experience. Locating objects using finderscopes and starhopping requires a lot of bending and stooping and contorting into positions you'd rather not be in, especially when bundled up in cold-weather garb. It's a lot of physical effort. With an LX200 you can stay lazily seated the whole time and let the scope do the work. You just do the looking.

With its capabilities, Meade's LX200 series is sure to change the way many amateur telescopes are built and many amateur astronomers explore the sky. But the bottom line is that the LX200 was just plain fun to use. □

REAL MARS



MARS IN 1992/1993

As Mars came to opposition in early 1993, its atmosphere remained largely free of dust, but thin clouds of water vapor scudded across the upper atmosphere. Here's a wrap-up of sights observed during apparition.

by Donald C. Parker
and Richard Berry

CLEAR SKIES ON MARS

SIMULATION

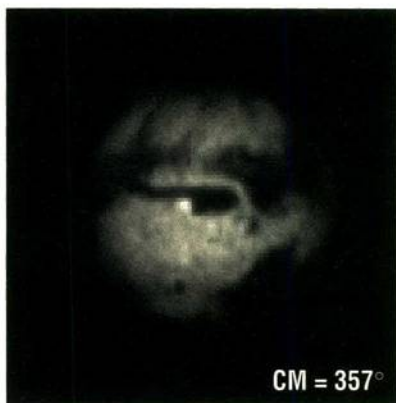
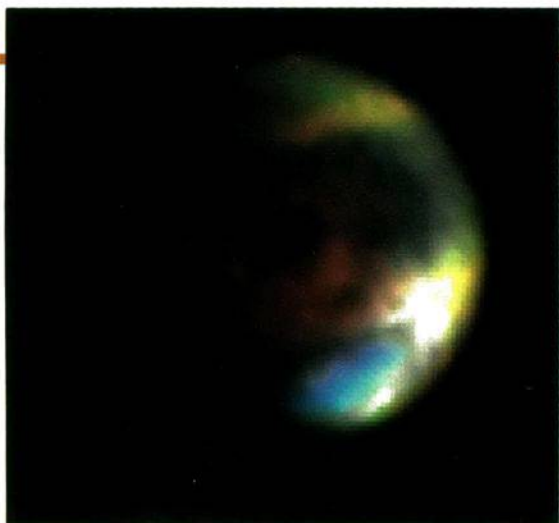


When Mars stood high in the sky at opposition on January 7, North American observers saw the conspicuous pipe shape of Sabaeus Sinus on its yellow-orange disk. Although the disk measured only 14.9 arcseconds across, planetary viewing conditions were excellent. For northern observers the planet was close to the zenith, so atmospheric turbulence robbed it of little detail. Even though Mars did not approach Earth as closely as it had in 1988 and 1990, the 1992-1993 apparition provided an excellent opportunity to observe the Red Planet.

Most observers looked for the conspicuous features on the disk, dark markings such as Syrtis Major. These serve as a stage upon which the actors — dust storms, polar caps, and clouds — perform the Martian drama, so observers learn these dark features to better delineate the dynamic activity of Mars. The visibility of these features is greatly enhanced by using color filters, particularly red Wratten 21, 23A, or 25 filters and yellow Wratten 8, 12, or 15 filters.

Of course the classic markings change, too. Seasonal winds move dust around the planet, covering dark rocks. Dust storms, especially big ones, move enough dust to change the markings in a single season. Over the years some markings have disappeared and new ones have appeared, like sets on a stage play. Observers continue to scrutinize the dust storms, polar caps, and clouds against these changing mark-

MARS REACHED OPPOSITION on January 7, 1993. Note the brilliant North Polar Cap and the dark inverted "pipe" called Sabaeus Sinus. On both limbs of the planet you can see conspicuous haze. In all of the images, south is at top.



MARTIAN MIDSUMMER

in the southern hemisphere was underway on August 16, when Mars appeared only 6.6 arc-seconds in diameter. The tiny white spot at the top of the image is the last remnant of the South Polar Cap. At the bottom of the image is the large, bright North Polar Hood and morning clouds over the arctic regions.

ings. The 1992-1993 apparition gave the audience of observers another opportunity to see all three in action. So you can better understand the play, we have matched CCD shots of the apparition with simulations of the familiar albedo markings.

Dust Storms

Dust rose in the thin Martian air last October in a small dust storm in the area of Chryse, a desert region just north of the Martian equator where the Viking 1 lander now stands mute. Mars and Earth were reasonably close to each other at the time, so terrestrial observers had a good view of the Red Planet. As late summer advanced in the southern hemisphere of Mars, alert observers in Great Britain, the United States, and Japan noticed tell-tale bright streaks across Chryse.

Seeing the dust storm required a good telescope, steady seeing, and a sharp eye. Chryse seemed a tiny bit brighter than normal, and through a red filter, the streaks were better defined. Because Martian dust is reddish, when winds raise dust from the Martian deserts, the cloud of dust appears bright as seen through red filters.

Observers watched the dust streaks in Chryse throughout October. Each streak lasted only a few days, although some lasted long enough to drift southward and partially obscure some dark features. By the first of November the dust had settled and the Martian atmosphere had returned to its normal clarity.

Although Mars is famous for its

globe-girdling dust storms, such storms are rare. Only five global dust storms — those of 1956, 1971, 1973, and two that appeared in 1977 — are well documented. Since that last global storm in 1977, a number of localized dust storms have blown up, but Mars has remained free of the spectacular planet-encircling events.

The short-lived dust storms seen this year are probably the rule rather than an exception. Without painstaking color-filter observations, no one would have known about the October dust events. A similar situation occurred in 1990, when the only humans to observe three major dust events were amateur astronomers in seven countries.

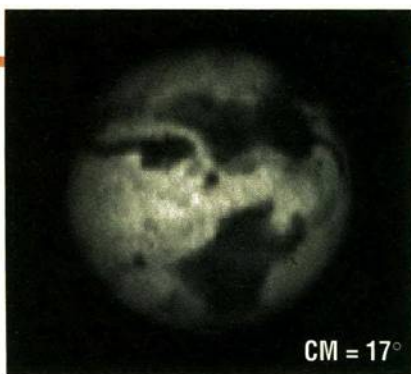
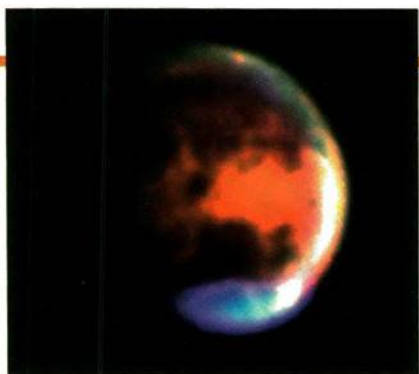
These observations have thrown new light on the nature of the Martian dust storms. Traditionally, astronomers believed that dust storms occurred only when Mars was closest to the Sun as the cold ground warmed and stirred up winds to raise dust. (Mars was last closest to the Sun on May 17, 1992; the next such date is April 4, 1994.) Recent studies by Leonard Martin of Lowell Observatory based partly on observations by members of the Association of Lunar and Planetary Observers (ALPO) have demonstrated that dust clouds can form at just about any time during the Martian year.

In a statistical analysis of thousands of Martian dust storms, ALPO Mars Recorders Jeff Beish and Don Parker showed three peaks in dust storm occurrences. One peak is in

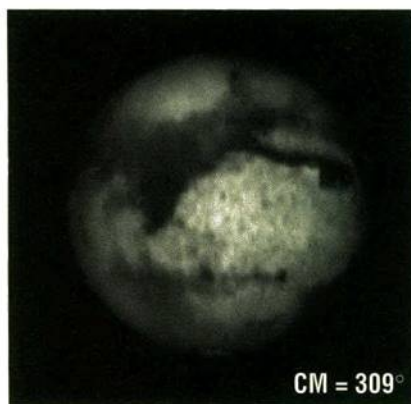
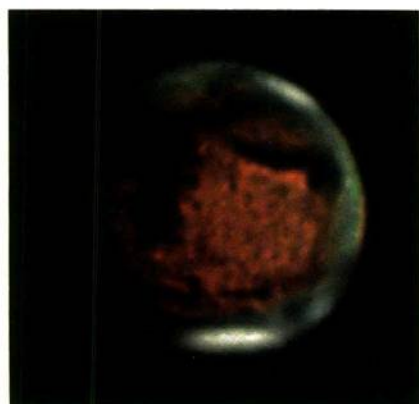
THE CHRYSE PLAIN is centered on the Martian disk in this image taken October 25, 1992. The late-winter North Polar Hood shines blue at the bottom of the image, and you can see prominent hazes on the morning limb (right side) of the disk. Mars rotates from right to left in these images.



The black-and-white comparison globes alongside each color CCD image were artificially generated by Richard Berry's Mars Simulation Mapper (MARSIMAP) software. These simulations show standard albedo features correctly placed to aid observers in identifying short-lived and changing features. In each case, the simulation shows Mars with the same central meridian and sub-Earth point as the real Mars. The simulated images do not show phase effects.



THE DARK ALBEDO FEATURES Baltia and Mare Acidaliu show through the blue haze of the North Polar Hood (bottom) in this image taken on October 25. Very bright morning hazes dominate the sunlit morning limb of the planet.



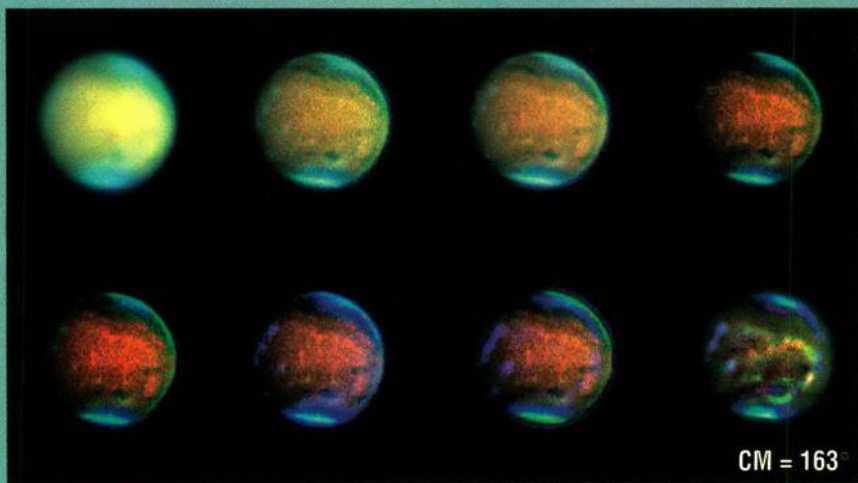
SPRING IN THE NORTHERN HEMISPHERE had arrived by December 8. The North Polar Cap, now free of the North Polar Hood, shines brilliantly at the bottom of the disk. The dark wedge-shaped feature is Syrtis Major. Pipe-shaped Sabaeus Sinus is also conspicuous. Note the bright morning limb clouds and hazes on the right side of the images.

What Should Mars Look Like, Anyway?

The classic drawings of Mars show a brick-red globe girdled with canals and dark, mysterious blotches. Photographs too often show a fuzzy, blurry disk that visual observers agree doesn't show half the detail they can see by eye. With CCD images, we can finally reproduce the exact telescopic appearance of Mars and, if we want to, enhance the original to show all of the features in a telescopic image of the Red Planet.

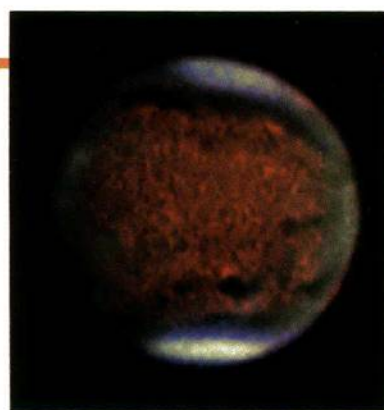
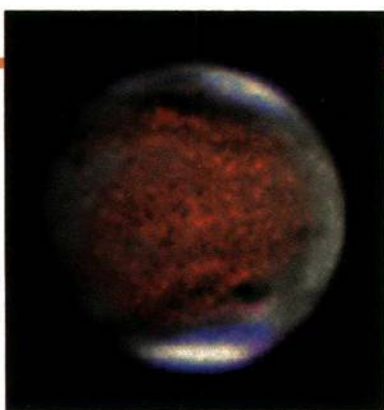
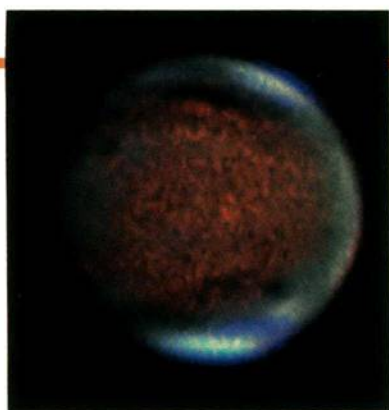
These images show the "real" Mars — in the upper left — and some variations on it. The real Mars is an exact reproduction of the color and intensity of the light falling on the CCD on Don Parker's telescope on the night of December 18, 1992. The image looks pale yellow-orange, and the planet's detail looks weak and washed out. This image nonetheless contains all the features visible in any later processing.

From top to bottom and left to right, here are some variations on Mars. Beside the real Mars in the top left position is an image gently sharpened by unsharp masking. With its gentle sharpening, the image closely resembles how the eye and brain of a skilled observer perceive Mars when viewing it in a medium-sized telescope. To its right is a more strongly sharpened image, an image in which small details have been contrast-enhanced by a factor of 12. It closely resembles Earth-based photographs of Mars taken with large telescopes. The right image in the top row shows this image with more contrast so that the colors appear stronger and darker. This is the image that most people would call "the best" picture of Mars.



At bottom left is "the best" image with its colors artificially enhanced by 20 percent. For someone interested in examining the planet for small color differences, this processing would be valuable. Next we see Mars with the contrast of its blue image doubled. This enhances all of the atmospheric features: the orographic clouds, polar hood, and morning hazes are now manifest. Beside it is a special processing designed to extract small-scale blue features. Atmospheric features pop in this view, especially the faint bands of clouds that stretch across the planet. Finally, at bottom right, all three colors have been processed for faint features. Garish images like this leave no cloud or dust storm unseen, but the price of seeing detail is seeing Mars at its ugliest.

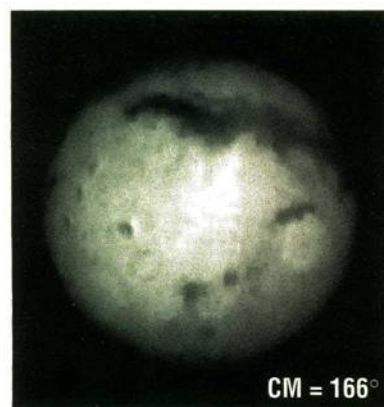
What does Mars really look like? The image at the upper left shows its "true" appearance. Our minds, however, can hold many images of Mars side-by-side, to select the view that shows best what we want to see.



CM = 144°



CM = 150°



CM = 166°

early northern hemisphere summer, another just after Mars' closest approach to the Sun in late southern spring, and the third during southern midsummer. Interestingly, until October 1992 no dust storms had ever been reported during the last third of Mars' southern summer.

Polar Caps

Early in the 1992-1993 apparition, the southern hemisphere of Mars was tilted toward Earth and the South Polar Cap was clearly visible. Observers watched the cap, largely carbon dioxide ice, shrink in the warmth of Martian southern summer. By mid-August the South Polar Cap appeared as a tiny white nubbin.

As Mars moved around its orbit, however, the orbital geometry of our view of the Red Planet changed. On August 30, when Earth passed through the plane of the Martian equator, terrestrial observers lost sight of southern polar regions and began instead to see northern polar regions.

The northern polar regions came into view during the Martian northern winter. All that observers could see was a thick cloud canopy called the North Polar Hood. As the northern Martian spring equinox approached, the hood thinned, permitting glimpses of far-northern dark mark-

ings. But it was not until the first week of December, just after the Martian vernal equinox, that the North Polar Cap, a composite of carbon dioxide and water ice, made its appearance.

Spring advanced, and the north cap shrank. Numerous rifts appeared along the edge of the cap as it shrank. One rift called the Rima Tenuis is so elusive that it had not been seen between 1913 and 1979, but at this apparition, Rima Tenuis reappeared. Between late December and February, observers Jeff Beish, Carlos Hernandez, and Dan Troiani saw it visually; Rudolf Hillebrecht imaged it with a CCD camera.

In the past Rima Tenuis has appeared later in the Martian year, suggesting that during the 1992-1993 apparition the cap shrank more rapidly than usual. Direct measurements of the size of the polar cap with a micrometer also suggest that the cap shrank faster than usual. Further evidence for an early shrinkage came from the unusually large number of Martian water-vapor clouds.

Clouds

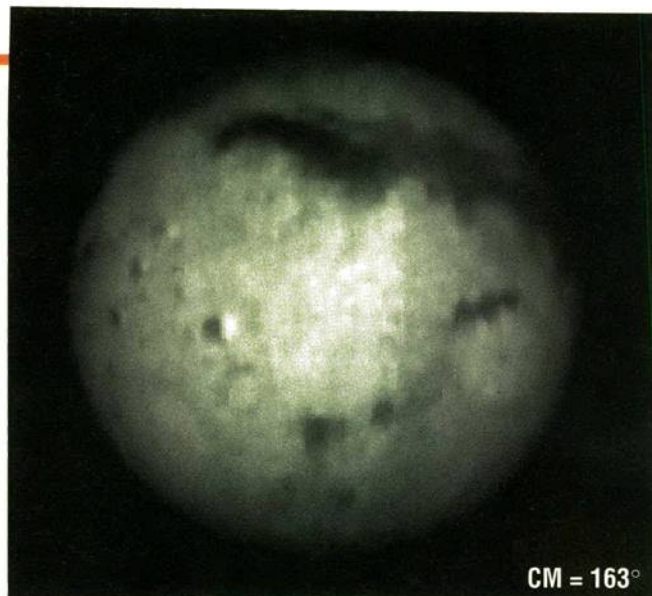
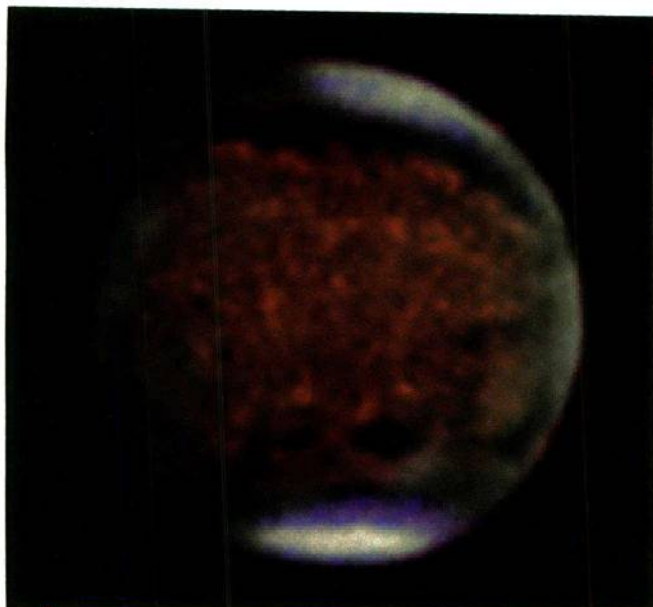
Many of the Martian clouds are seasonal, and their behavior is tied closely to the behavior of the polar caps. One sensitive indicator of over-

A MARTIAN ROTATION SEQUENCE

shows the planet's appearance at the end of 1992. These three images of Mars (upper) were taken over a 92-minute period on the evening of December 21. As Mars rotates you can see bright orographic clouds that form on warm Martian summer afternoons over the slopes of the giant Tharsis volcanoes.

all cloud formation is the appearance of orographic clouds. These small white or bluish clouds, like their terrestrial counterparts, consist of water-ice crystals that form when warm moisture-laden air rises and cools as it ascends mountain slopes. The clouds form near the planet's giant equatorial volcanoes in the Tharsis region and develop during Martian afternoons. They increase in size and brilliance as evening approaches.

Orographic clouds appear most frequently in the Martian spring when the water-vapor content of the planet's atmosphere is highest. Observers expected orographic clouds during the second half of the 1992-1993 Mars apparition and were surprised when orographic clouds emerged in mid-December, a full month ahead of schedule. By the middle of January, orographic clouds were not only conspicuous over the



CM = 163°

OROGRAPHIC CLOUDS mark the great volcano Olympus Mons on December 21, 1992. These occur when moisture-laden air rises over the giant volcanoes of Tharsis, cools, and condenses.

great Tharsis volcanoes but were also visible over the smaller Elysium volcanoes. This suggests that the Martian atmosphere was particularly damp.

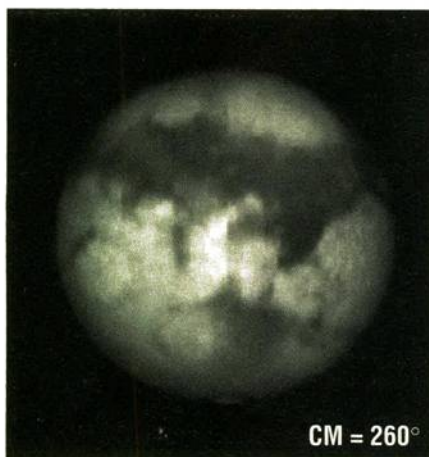
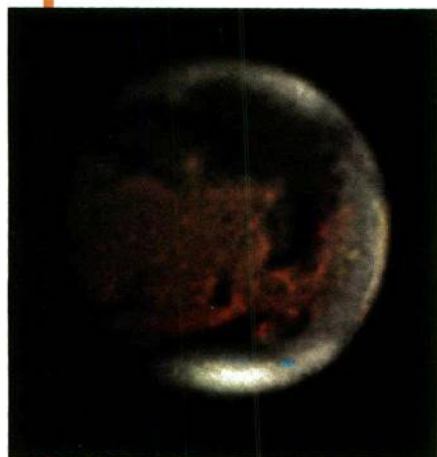
Observers see orographic clouds best in blue light. When you view Mars through a Wratten 38A blue fil-

ter, the albedo features become inconspicuous, but the atmospheric features such as limb arcs — atmospheric hazes visible over the planet's limbs — and cloud streaks stand out brighter than the rest of the atmosphere. Orographic clouds sometimes show up as brilliant dots that in blue light give Mars the appearance of a giant domino.

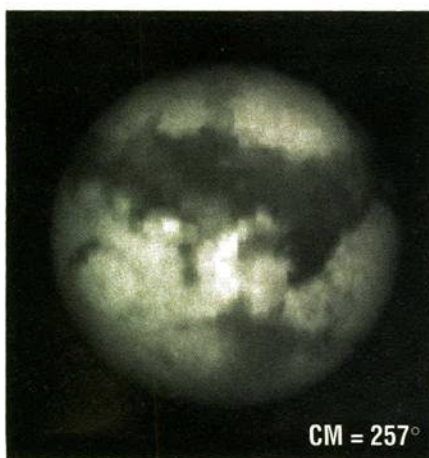
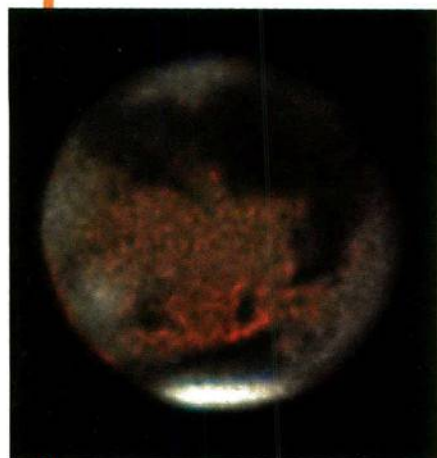
The main water-ice reservoirs for the southern hemisphere reside in the great low-lying impact basins Hellas and Argyre rather than in the South Polar Cap, which is largely composed of frozen carbon dioxide. Hellas and Argyre lie in the high southern temperate latitudes, so their water ice sublimates earlier than it would if it were nearer the pole.

The North Polar Cap, on the other hand, is the primary water-ice reservoir for the northern hemisphere. The northern cap consists of a water-ice core covered by a mantle of frozen carbon dioxide. When the carbon dioxide sublimates, the water-ice core remnant retreats — and the water-vapor content of the Martian atmosphere surges. Since this remnant lies at much higher latitudes than Argyre or Hellas, the bulk of the water doesn't evaporate until late northern spring and early summer.

Because the North Polar Cap re-

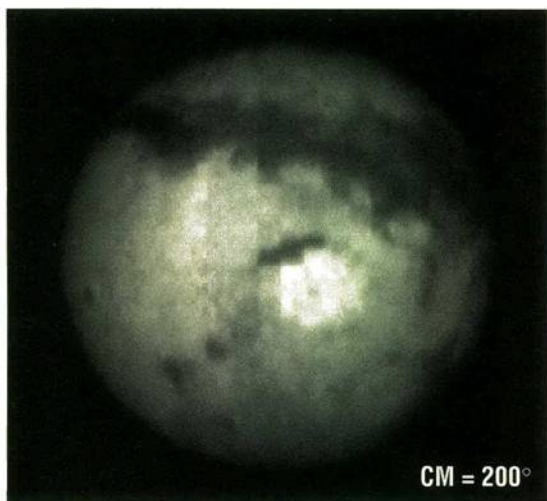


CM = 260°

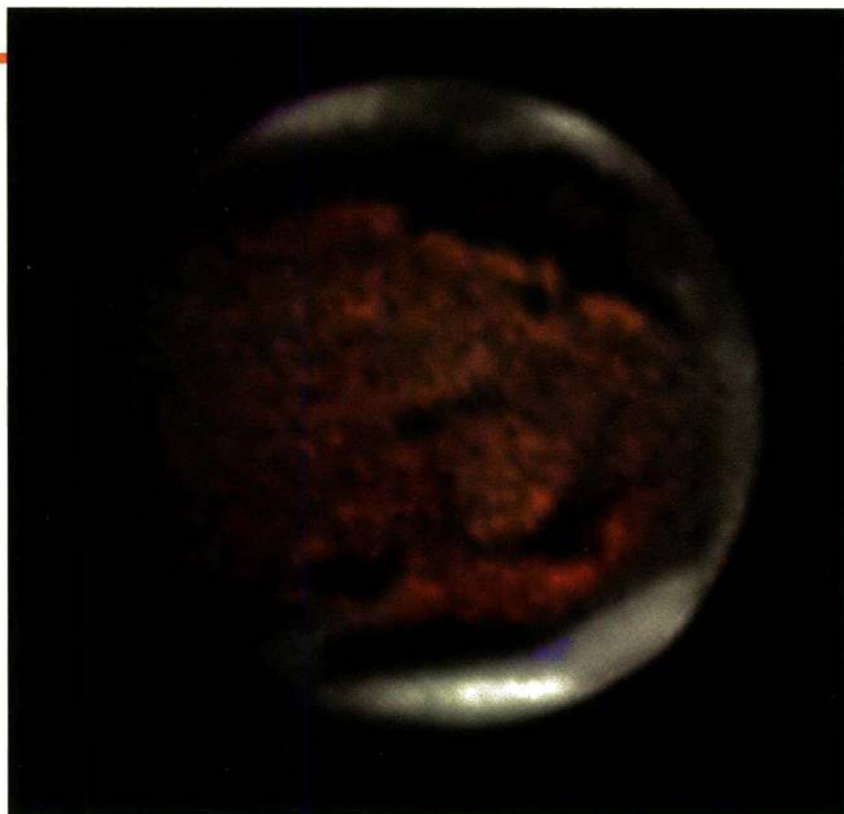


CM = 257°

THE ELYSIUM VOLCANIC SHIELD changed dramatically between December 13 and January 19. In December there were no clouds, but by January as Martian spring progressed, brilliant orographic clouds formed daily over the volcanic shield. By late January, morning and southern limb hazes had begun to diminish.



DELICATE WISPS OF CLOUD called equatorial band clouds extend from the morning to the evening limb of Mars on December 18, 1992. These clouds are difficult to see, but they show up clearly in images taken with CCD cameras. You can see a cloud front coming off the evening side of the North Polar Cap.



treated faster than normal during the 1992-1993 apparition, it spilled its water vapor into the Martian atmosphere more quickly. This would explain the early appearance of both the orographic clouds and the Rima Tenuis.

The Martian climate varies, of course, so that each apparition has its own characteristic signature. During the early 1980s observers noticed a warming trend on Mars, evidenced by the presence of more clouds and smaller polar caps. It may be that this trend is continuing and that we see the evidence with our telescopes.

CCD Meteorology?

Observers sighted other interesting clouds in 1992-1993. During the early part of the apparition in the autumn of 1992, morning limb hazes consisting of crystals of carbon-dioxide ice were prominent. As the apparition progressed, clouds appeared near both poles and just east of Syrtis Major in the great Libya-Isidis depression.

Perhaps the most exciting clouds were equatorial band clouds composed of carbon dioxide and water ice. Before this apparition, observers thought such clouds to be exceedingly rare, but during the latter half of this apparition equatorial band clouds were seen and imaged on numerous occasions. Many images taken during this apparition were made with CCD cameras. Because



GRAY HAZES FORMED over the Libya basin, east of Syrtis Major on December 11, 1992.

properly calibrated CCD images are very precise, features that are only 1 to 2 percent brighter than the planet itself can be enhanced. With electronic image processing, we can finally see these clouds clearly.

The apparent diameter of Mars will be small for the next two Martian apparitions on February 12, 1995, and March 17, 1997. However, the rich harvest of observations from the 1992-1993 apparition is encouraging. Interest in Mars will be high during those apparitions, with visual and CCD observations from amateur astronomers complementing data from the Mars Observer spacecraft, due to

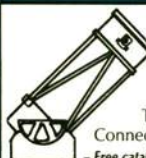
arrive at Mars in August. Furthermore, during both coming apparitions, the northern hemisphere of Mars will show its face during the spring and summer seasons, presenting observers on Earth two first-rate opportunities to explore the dynamic features of Mars. □

Don Parker and Richard Berry have teamed for two years to produce outstanding CCD images of the planets, with Don taking the images from his observatory in Coral Gables, Florida, and Richard creating software to calibrate and process the images.

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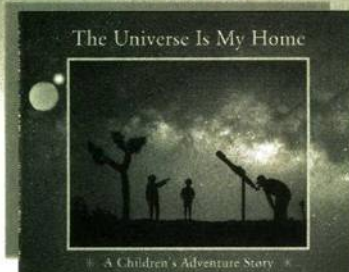


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CHUCK AND HOWARD'S EXCELLENT ADVENTURE

One night Chuck and Howard decided to go observing. They had a secluded star-watching site on Steens Mountain, Oregon, a 9,773-foot peak where they could be guaranteed a dark sky. So last September Chuck (Dethloff, president of the Rose City Astronomers) and Howard (Banich, his friend) prepared for the 8-hour trip and left Portland with images of galaxies dancing in their heads.

"As we headed up the mountain on the rough and rocky road," says Chuck, "we saw clear sky overhead, tinged by the brownish-yellow specter of Pinatubo dust on the horizon. We knew that many great sights awaited us when the Sun went down."

Chuck and Howard pulled into the site of the 1991 Oregon Star Party, on Moon Hill Road. For two nights the adventurers worked their craft with 24-inch f/5 and 20-inch f/5 reflectors. They also brought a 12.5-inch f/8 reflector. How did they tear themselves away from the two bigger scopes to use the 12.5-incher? They didn't. In the end, it sat unused.

"Skies were exceptionally transparent and the seeing seemed steady," says Chuck. "With direct vision the central star in the Ring Nebula was visible for several seconds at a time. Altogether, seven stars were embedded in the nebula's glow. We took a tour of the Veil Nebula, the whole thing, bit by bit. We came away with a new appreciation of seeing an old friend in a different light."

Many fainter attractions caught their attention. "The Sculptor galaxy NGC 55 was maybe 5° above the horizon, yet it appeared as bright as nearby NGC 253. It was incredible!" The California Nebula, reports Chuck, was a serious challenge. "It required our lowest power and an H-beta filter, but it was there. It's a big, ghostly thing, with several streamers glowing faintly against a starry backdrop. Awesome!"

Chuck and Howard also spotted an object considerably more distant than the others — the twin quasar 0957+561AB, a gravitational lens quasar. We see a faint double image of this remote object because a massive galaxy between it and us bends the light into a cosmic mirage. "It took surprisingly little effort to find this field, near the galaxy NGC 3079 in Ursa



Major," says Chuck. "Sixteenth-magnitude is faint and about all we could see was a faint smudge."

"But it was there."

Mars at Opposition. Of the reports we received from the 1993 opposition of Mars, the one from Matthew Boulton of Worcestershire, England, was among the most painstaking. Complete with sketches and notes, Boulton's account follows the Red Planet during January and February 1993.

"This year I glimpsed details I hadn't seen previously," remarks Boulton. "I used a 10-inch reflector at magnifications up to 230x. I found the Martian longitudes between 30° and 90° to be the most detailed. Margaritifer Sinus was paler than usual this time around, with the much darker Oxia Palus on its edge. Mare Erythraeum seemed to be broken up into dark mottlings."

Although the disk of Mars was smaller than it was during the oppositions of 1988 and 1990, Boulton found plenty to observe. "I thought the most prominent feature in the planet's northern hemisphere was Mare Acidalium, appearing patchy and bordering the polar cap. On February 1 the Chryse plain seemed particularly bright. Although Mars will be smaller yet at its 1995 opposition, I'll definitely be out there watching it."

Spotting Details on Uranus. "Most of my views of Uranus have shown me a small, greenish disk with a little limb darkening," says Gary T. Nowak of the Vermont Astronomical Society in Essex

A GREENISH GLOW enveloped the horizon (above) the night Chuck Dethloff and Howard Banich observed from Steens Mountain, Oregon. The aurora capped a memorable session of deep-sky viewing. A significant planetary event of recent months was the Martian opposition in January 1993. Matthew Boulton's sketch of Mars (left), made with a 10-inch scope at 320x on January 12, 1993, shows Elysium as the bright circular feature.

Junction. Then, on July 21, 1992, Nowak turned a 10-inch f/20 Tri-Schiefspiegler toward the distant planet. "At 317x I had my first good views of Uranus," he says. "The planet's northern limb was clearly darker than the southern. I saw the same thing on August 7 and was intrigued that detail was visible on such a distant world."

But the viewing of Uranus would get better for Nowak. "On September 19 I viewed the planet at 317x using a Wratten #8 yellow filter. To my surprise, I saw a prominent dark band on the planet that was easier to see with the filter than without. On October 1, I observed a small, bright white zone on the planet."

Nowak feels that observers should view Uranus (and Neptune) at high power and resolution this summer. Lesser amounts of dust in Earth's atmosphere relative to last year may make details on Uranus slightly easier to see.

Jupiter's Changing South Equatorial Belt. In early 1993, Jupiter's usually dark South Equatorial Belt was nowhere to be seen. But in early April, the belt began to erupt and return to view. Have you observed Jupiter's changes? If so, we'd love to get your sketches, reports, and photos for future editions of Reader Reports. □

ASTRONOMY wants to hear about your observations of the sky. Please send reports, sketches, and photographs to David J. Eicher, Reader Reports Editor, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187.

THE WARM GLOW OF SUMMER NIGHTS

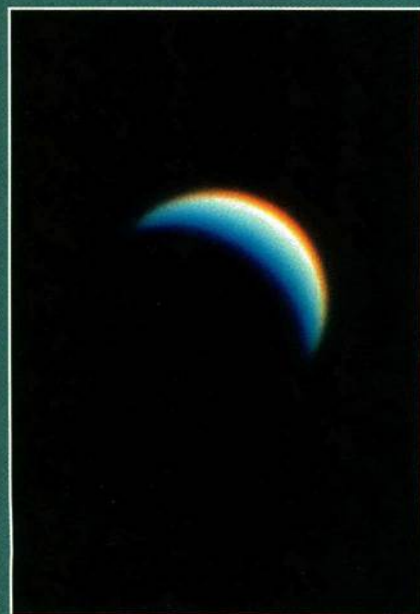
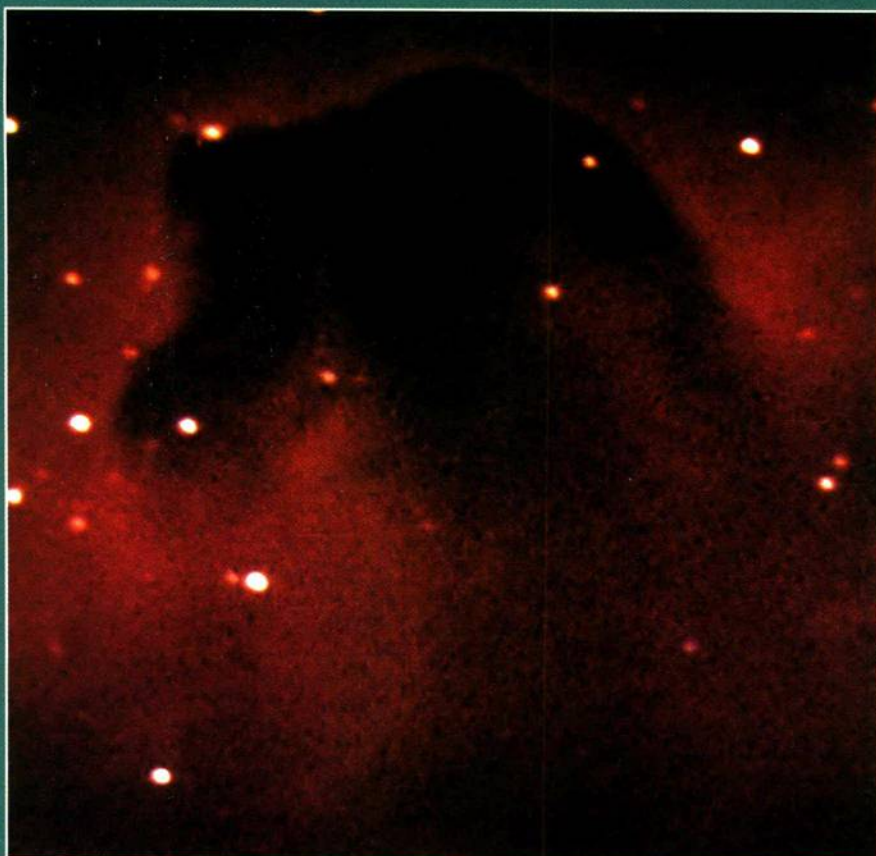
Nothing beats an astronomical observing session — unless it's one that's coupled with a campout near Yellowstone National Park. Ed Vega's photo (opposite page) shows stars arcing around the pole over his camp near Yellowstone. The image wins this month's \$100 Best Astrophoto award. Vega took the photo with a 24mm lens and Kodachrome 200 film.

Long exposures of more distant game — deep-sky objects — continue to push the boundaries of astronomical imaging. Patrick Martinez and Pierre-Michel Berge used a 500mm lens and a Spectra-Source Lynxx CCD camera to capture a digital image of the Orion Nebula (below left).

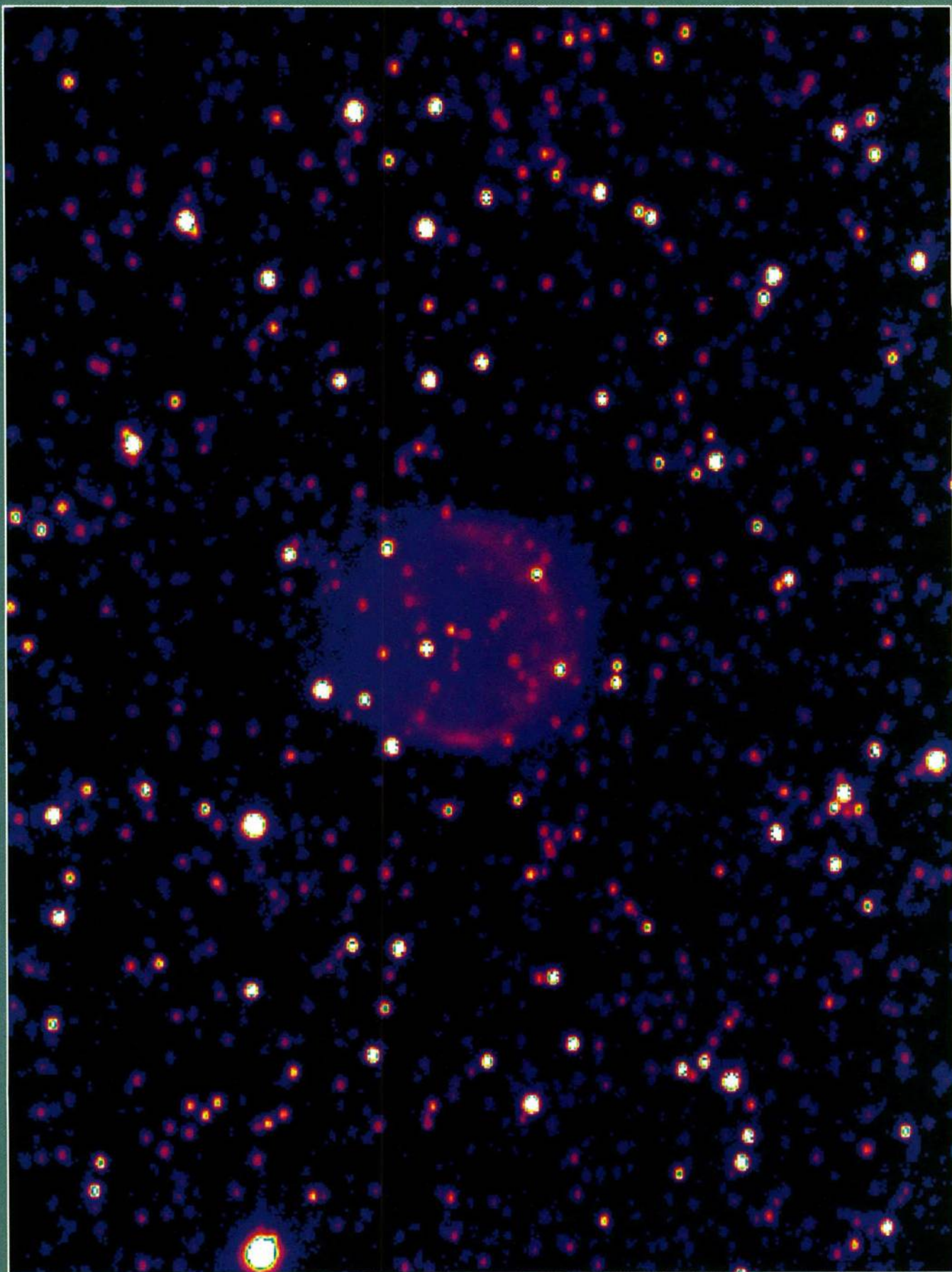
Jack Newton captured magnificent detail in the Horsehead Nebula (top left) and the Crab Nebula (opposite page, bottom left) with his 25-inch reflector and an SBIG ST-6 CCD camera.

The meeting of deep-sky object and solar system wanderer happened on February 9, 1993, when Comet Schumacher passed in front of the California Nebula (NGC 1499) in Perseus. Sang Ho Cho of Taejon, South Korea, captured the event (opposite page, bottom right) with his 4-inch refractor. The comet is shown with an arrow.

Venus floated brightly in the evening sky early in 1993. Don Bruns recorded the planet's delicate phase on March 4, 1993 (below), using an 8-inch SCT (stopped down to yield a focal length of 30 meters), Ektar 25 film, a 10-second exposure, and a Stellar Products AO-2 adaptive optics system.







THE GHOSTLY SPHERE of planetary nebula NGC 6781 in Aquila stands out against the backdrop of Milky Way stars. Ronald W. Kohl used a 20-inch Cassegrain telescope and a Photometrics Star I CCD camera for the 3-minute exposure.

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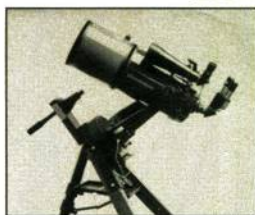
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8".....95.00	8".....85.00
10".....109.00	10".....99.00
11".....119.00	11".....109.00
12.5" to 13.1".....149.00	12.5" to 13.1".....129.00
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Minimum order of 10 eclipse filters in any combination. Please add appropriate shipping/handling. 10 units: \$30. Plus \$1.00 for each additional 10 units. Minimum credit card order of \$25.00. Quantity discounts available starting at 100.

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Expert Astronomer, program written by Etlon Software, distributed by Expert Software, P. O. Box 144506, Coral Gables, FL 33114-4506. Phone (800) 759-2562. Price: \$49.95. Minimum requirements: Macintosh Plus, 2 MB of memory (4 MB if you use System 7), System 6.0.4, and a hard disk with 1.3 MB of free space. Supports ImageWriter, StyleWriter, and LaserWriter printers.

The low-cost IBM PC-compatible program called Expert Astronomer (see the December 1992 AstroBytes) has a Macintosh cousin. It too is low priced, available for around \$30 in many computer and department stores. Like most planetarium-type programs, Expert Astronomer plots sky maps, draws constellation figures, and shows the positions of the planets and deep-sky objects such as galaxies and gaseous nebulae. Its database contains over 9,100 stars, 6 comets, 4 asteroids, 12 planetary satellites, 110 deep-sky objects from the Messier list, and numerous objects from the *Revised New General Catalogue*.

Fifteen preprogrammed views, such as two eclipses, the solar system, planets in the sky, deep-sky objects, and the evening and dawn skies come with the program. Mouse tools let you zoom in on an object or identify which object you are looking at. Star identifications include common names and Bayer, Yale Bright Star, and some HD designations. You can set the magnitude limits, determine which objects to plot, and choose symbols or disks to represent the planets.

The software gives you control over plotting the sizes of dots used for stars. You can select a white or dark sky for your maps and choose different grid

spacings if you wish your maps to have a coordinate grid — choices include horizon, equatorial, ecliptic, and galactic coordinates.

Expert Astronomer lets you hover above a planet and watch its satellites go by. It also includes a conjunction finder, useful for finding eclipses and close groupings of planets. Once you find an interesting event, use the time lapse feature to watch the event unfold on the display. You can not only

watch a solar eclipse as it appears in the sky, but also track the path of the Moon's shadow as it races across Earth's surface. It's not very accurate (the map for the July 11, 1991 eclipse shows totality missing Hawaii, for example), but this feature is unusual for a low-cost program and it demonstrates eclipse concepts well.

The search feature needs some improvement, because there are no lists to choose from for finding the planets, common stars, or constellations. You have to know the exact name used in the database; for example, Comet Halley is listed under Halley's comet. You can use fewer letters: "Halley" or even "Hal" found the comet, "Jup" found Jupiter, and "Grigg" found the comet Grigg-Skjellerup. But be careful — "Sat" found Mercury not Saturn. Searching for comets or deep-sky objects is difficult unless you already know which objects are in the database.

Like its PC cousin, the Mac version of Expert Astronomer is a bargain. So if you've been dragging your feet about buying a planetarium-type program because of cost, try Expert Astronomer. It provides the basic tools needed for exploring the sky and has a lot of advanced features, such as the conjunction finder, for a low-cost program. — Dave Bruning

NEW SOFTWARE

Astropoint IV, Dale Ferguson, 22341 Sprague Road, Strongsville, OH 44136. Price: \$29.95, plus \$1.20 for shipping and handling. Minimum requirements: IBM PC-compatible computer. Both 5 1/4" and 3 1/2" disks are provided. Write for

information about Apple II and Atari versions of the program.

Astropoint IV tells you where in the sky to find bright stars (down to magnitude 4.5), Messier objects, and the planets. It will precess coordinates, calculate sidereal time and universal time, and provide altazimuth and equatorial coordinates for objects. An "observing mode" provides continuously updated object positions to assist in finding an object using its coordinates.

Satellite Pro, Zephyr Software, 1900 Murray Avenue, Pittsburgh, PA 15217. Phone (800) 533-6666. Price: \$149.95, plus \$4 for shipping and handling. Minimum requirements: IBM PC-compatible computer, hard disk, and EGA monitor.

You can follow up to 200 Earth-orbiting satellites simultaneously with this program. Satellite Pro comes with a database containing orbital element sets for 650 satellites. The program uses these element sets to calculate the orbits and positions of the satellites. The database can hold data for up to 20,000 satellites and has its own editor for adding and updating elements. The program can generate orbital elements from launch parameters and includes information about how to obtain element sets for other satellites via mail or modem.

You can produce maps showing the path of the satellite over Earth or against the starry sky in either altazimuth or equatorial format. Satellite Pro lets you change stellar magnitude limits down to 7th magnitude. It also plots the positions of the Sun, Moon, and planets on sky maps.

Personal Observing Log (3.0), Ohio Star Software, 8919 Deep Forest Lane, Centerville, OH 45458. Shareware — registration fee: \$20. Minimum requirements: IBM PC-compatible computer and Windows 3.X.

Record your observing notes with Personal Observing Log. The program comes with a database of over 1,200 objects and allows you to add others. You can record up to 50 observations per object and define up to 20 pieces of equipment to keep track of scopes, filters, and eyepieces used. For each object, the software computes the map pages for Sky Atlas 2000.0 and Uranometria 2000.0. Search features help you sort through the

database to pick the objects for your next observing session.

Voyage to the Stars (CD-ROM), Smithsonian collection, Astronomical Research Network, 206 Bellwood Avenue, Maplewood, MN 55117. Phone: (612) 488-5178. Price: \$149.95, plus \$5 for shipping and handling.

Volume four in this series of CD-ROMs contains images of about 200 objects photographed by Rudy Schild of the Harvard-Smithsonian Center for Astrophysics. The CD-ROM includes software for viewing the images — ArView for Windows 3.1 and ProVision software for Macs and PCs.

Principal Galaxy Catalogue (CD-ROM), Observatoire de Lyon, Base de Données Extragalactiques, 9 avenue Charles-André, 69561 Saint-Genis-Laval Cedex, France. Price: \$90, includes delivery charges. Includes programs for IBM PC-compatible and Macintosh computers. (Cartridges and tapes for UNIX-based systems are also available.)

This CD-ROM includes information about more than 73,000 galaxies, including descriptions, coordinates (both B1950.0 and J2000.0), and almost 135,000 cross-identifications as well as magnitudes, sizes, inclinations, velocities and many other parameters describing the galaxies. The disk is in standard ISO 9660 format, so it is readable on most CD-ROM drives. Accompanying software permits you to create data files using galaxy names or characteristics and print maps with Postscript printers.

Correction to Review of The_Sky

A hardware problem with our laser printer prevented us from properly evaluating the quality of sky maps produced by The_Sky. (See the May AstroBytes.) Maps produced in high-quality mode on a laser printer, even at low resolution (75 dots per inch), are excellent. And you can adjust type styles and sizes to customize labels on your maps.

Also note that The_Sky doesn't remember temporary changes of observing location: All changes must be saved to the location list for proper use of the program. This affected our interpretation of conjunction times, eclipse paths, and the times of New and Full Moon. The_Sky actually calculates these items with good precision. □

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Astronomy Books

DEEP-SKY OBSERVING

Beyond the Solar System, by David J. Eicher, (AstroMedia, 1992), ISBN 0-913135-10-0, 80 pages, softcover, \$12.95.

Beginning astronomers often confuse the Messier list with the list of the best deep-sky objects. But experienced observers know better. Some spectacular deep-sky objects weren't listed by Charles Messier in his catalog — objects such as the Double Cluster in the constellation Perseus and the North America Nebula in Cygnus. This book presents 100 objects, on and off Messier's list, that are worth your attention.

Any list of the 100 best of anything reflects someone's opinion. In this case, you get Dave Eicher's opinion of the 100 best deep-sky objects. Dave was editor of *Deep Sky* magazine for 15 years, so his opinion is respectable.

He includes 8 double stars, 5 variable stars, 19 open and 11 globular clusters, 6 dark nebulae, 10 planetary nebulae, 18 diffuse or emission nebulae, and 23 galaxies. The selection is pretty good overall. I consider several of the choices, such as the Horsehead Nebula, the California Nebula, and the Cocoon Nebula, to be difficult objects for beginners. Instead I would have included the multiple star system Epsilon Lyrae, the open cluster NGC 2362, and the barred spiral galaxy NGC 55.

Each object listing includes a short description of the object as well as its position, magnitude, and angular size. The listing also describes a star-hopping path to the object. Black-and-white photos taken by the finest amateur astrophotographers accompany the listings. Unfortunately, the wide-field shots of the double and variable stars aren't helpful for finding the star of interest. The stars should have a pointer or other device to highlight them; otherwise you need to use a star atlas to pick out the star.

In addition to the black-and-white photos, twenty-one color photographs fill a special portfolio of deep-sky objects. This collection of photos alone is almost worth the price of the book.

The photos and descriptions make this book a good value. I believe beginning astronomers and experienced deep-sky observers alike will find this a useful addition to their library. — Alan Goldstein

The Deep Sky Field Guide to Uranometria 2000.0, by Murray Cragin, James

Lucyk, and Barry Rappaport, (Willmann-Bell, Inc., 1993), ISBN 0-943396-38-7, 408 pages, hardcover, \$49.95.

This field guide provides information about 14,000 deep-sky objects contained in the charts of *Uranometria 2000.0*. For each chart, the authors separate the objects by type — galaxies, open clusters, globular clusters, bright nebulae, dark nebulae, and planetary nebulae. Within each type, they list objects by increasing right ascension and give the name, alternate names, magnitude, size, and observing notes, plus other information depending on type.

The book also includes an erratum to *Uranometria 2000.0* and an extensive index of objects by name and alternate names. All deep-sky observers will want a copy of *The Deep Sky Field Guide* to plan their next observing session.

Space

The Dream Machines, by Ron Miller, (Krieger Publishing Company, 1993), ISBN 0-89464-039-9, 744 pages, hardcover, \$112.50.

This is an illustrated history of spaceships, from the earliest mention of an imaginary trip to the Moon by Antonius Diogenes about 2,000 years ago to the prototype spacecraft envisioned in the 1990s. Spaceships in literature and popular media, such as movies and television, receive as much attention as actual craft built by NASA and other space agencies.

Many original illustrations by Ron Miller and Rick Dunning accompany Miller's text, as well as black-and-white photographs, engravings, and blueprints of spaceships from other sources. Over 500 pictures adorn the book. An appendix lists information about early rocket-powered aircraft, space planes, re-entry capsules like the Mercury and Apollo capsules, and designs for space transport vehicles like the space shuttle.

Almanac

Explanatory Supplement to the Astronomical Almanac, edited by P. Kenneth Seidelmann, (University Science Books, 1992), ISBN 0-935702-68-7, 752 pages, hardcover, \$65.

This extensive revision updates and expands the content of the *Explanatory Supplement*, last printed in 1961. It provides definitions for many astronomical terms and shows how astronomers calculate the data contained in the annual *Astronomical Almanac*. Although the book

is not intended solely for professional astronomers, it does assume knowledge of spherical geometry, calculus, and matrix algebra.

It starts with an introduction to positions and time in astronomy and then shows how to compute the orbits of the planets and their satellites. Also described are Earth's shape, physical characteristics of the planets, eclipses of the Sun and Moon, conjunctions, and risings and settings. A chapter on calendars and another on the history of almanacs round out the information provided by the *Supplement*.

Historical Books

On the Revolutions, by Nicholas Copernicus, translation and commentary by Edward Rosen, (The Johns Hopkins University Press, 1992), ISBN 0-8018-4515-7, 452 pages, acid-free paper, softcover, \$39.95.

Minor Works, by Nicholas Copernicus, translation and commentary by Edward Rosen with the assistance of Erna Hilfstein, (The Johns Hopkins University Press, 1992), ISBN 0-8018-4516-5, 373 pages, acid-free paper, softcover, \$39.95.

These reprints of earlier books printed in Poland provide translations of Copernicus' greatest work *De revolutionibus orbium coelestium* and lesser works, such as his *Commentariolus*, in which Copernicus first proclaimed that Earth is a planet in motion. *Minor Works* also contains translations of some of Copernicus' letters and various documents he wrote as a church canon.

Erratum for Astrophysical Data

In the February issue, we noted that a number of errors exist in Kenneth Lang's *Astrophysical Data: Planets and Stars*. The publisher now includes with every copy of the book an erratum that corrects these errors. Previous purchasers of the book may obtain the errata from Springer-Verlag, 175 Fifth Avenue, New York, NY 10010 or by calling (800) 777-4643.

Other Books Received

An Introduction to Astrophysical Hydrodynamics, by Steven N. Shore, (Academic Press, 1992), ISBN 0-12-640670-7, 452 pages, acid-free paper, hardcover, \$49.95. A specialist's guide to shock waves, turbulent flows, accretion mechanisms, and magnetic fields in astrophysical settings. □

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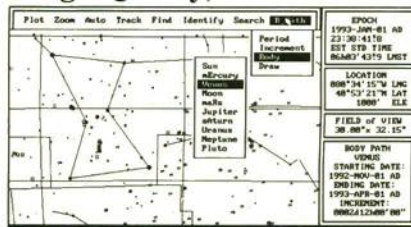


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1 Parks Astrolight Telescopes

Parks Optical has reintroduced their Astrolight Newtonian reflectors. Two models are available: a 6-inch f/6 (shown) and 6-inch f/8. Each features a 1.25-inch focuser, 6x30 finderscope, and a Super Polaris German equatorial mount. The mount includes slow-motion controls, setting circles, and an adjustable-height wood tripod. Single- and dual-axis DC motor drives and a polar alignment scope are optional.

Parks Optical, 270 Easy Street, Simi Valley, CA 93065, (805) 522-6722. Each model: \$1,600.



2 A Sidereal Clock

The new SC110 Sidereal Clock from AWR Technology displays both universal and sidereal time and has a built-in metronome that beeps every second (with a longer beep at the minute) for timing exposures and celestial events. The SC110 requires 12 volts DC and has a built-in 9-volt battery backup that can power the clock for up to 50 hours.

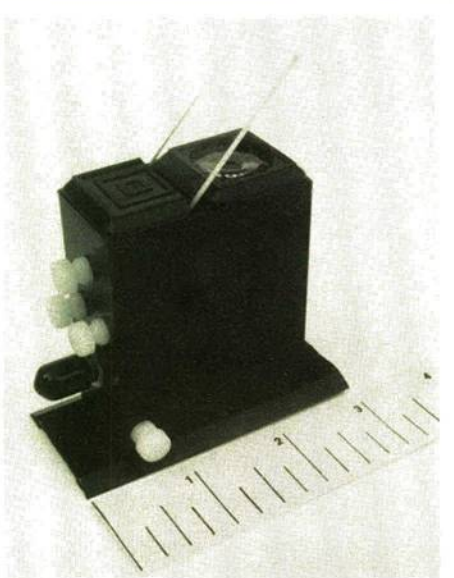


AWR Technology, 67 Thornbridge Road, Deal Kent, England CT14 9DZ. Phone: 011-44-304-365-918. £79.

3 QuikFinder Finderscope

QuikFinder is a new reflex sight that projects a 2°-diameter red circle onto the night sky in focus with the stars, helping you aim your telescope. The unit measures 3x2x1 inches and features black-anodized aluminum construction. It comes with a baseplate that attaches to the telescope without drilling. The QuikFinder can be easily removed from the baseplate for storage or for use on other baseplate-equipped telescopes.

Rigel Systems, 26850 Basswood Avenue, Rancho Palos Verdes, CA 90274, (310) 375-4149. Quik-Finder and baseplate: \$39.95 (lithium battery included); additional baseplates: \$7. Shipping: \$2 for first item, \$1 for each additional item.



4

Wide-field Maksutov Telescope

The MC90 from Cosmos Ltd. is a 3.5-inch spotting scope that can also be used as an astronomical telescope or 500mm f/5.6 telephoto lens. It uses Maksutov-Cassegrain optics and includes a two-element field flattener lens. Closest focus is 5 feet. The tube weighs 2.9 pounds, is 8.25 inches long, and accepts standard 1.25-inch accessories. Optional accessories include a micro-motion table tripod, 90° star diagonal, erect-image 45° diagonal, 2x Barlow lens, T-mount camera adapter, and a selection of Plössl eyepieces.

Cosmos Ltd., 9215 Waukegan Road, Morton Grove, IL 60053, (800) 643-2351. MC90: \$275; table tripod: \$47; star diagonal: \$45; erect-image diagonal: \$57; Plössl eyepieces: \$57 each; Barlow: \$47; T-mount adapter: \$15.

This department presents new product announcements issued by their manufacturers. The product information is as supplied by the manufacturers or distributors. All prices are suggested retail. Suppliers are invited to send their product announcements to the attention of Alan Dyer.

5 Aluminum Equipment Cases

Zero Centurion's new foam-lined equipment cases come in two sizes: a 13x8x6-inch case (model #103XD) and a 13x21x6.5-inch case (model #105XD). Both are available in anodized silver or black powder-paint finishes. Each comes with six movable dividers to customize compartment sizes.

Zero Enclosures, 200 North 500 West, North Salt Lake, UT 84054, (801) 298-5900, FAX (801) 299-9450. Model #103XD (silver or black): \$243.85; Model #105XD (silver or black): \$267.20.



6 Weather Satellite Demodulator

The MultiFAX portable WEFAX (Weather Facsimile) demodulator works with any IBM-compatible computer to display real time high-resolution weather satellite images. The WEFAX connects to the computer's parallel printer port and is designed for use with laptop or notebook computers in the field, making it ideal for use on eclipse chases and at remote observing sites. A receiver and simple antenna are needed to complete the weather satellite station.

MultiFAX, 143 Rollin Irish Road, Milton, VT 05468, (802) 893-7006. \$389.



7 MiniTrak Drive Corrector

Vogel Enterprises' new palm-sized MiniTrack produces 115 volts AC from any 12-volt DC source and is suitable for powering AC-motor-equipped telescopes. For guiding astrophotographs, the MiniTrack provides fast/slow pushbuttons and a variable speed control and features a stable quartz-controlled oscillator for accurate speed setting. The MiniTrack includes a power cord for use with a car cigarette lighter.

Vogel Enterprises, Inc., 38W150 Hickory Court, Batavia, IL 60510, (800) 879-TRAK. \$99.95.



8 A Calendar for Backyard Astronomers

The Ventura County Astronomical Society has issued their new 1993-94 Observer's Calendar, which provides sunset and moonrise times (for Southern California) as well as meteor shower and major star party dates for the period from June 1993 to May 1994. Each month's calendar is accompanied by a black-and-white astrophoto.

Ventura County Astronomical Society, P.O. Box 982, Simi Valley, CA 93062. \$7.50 each; 5 or more: \$7 each. Includes shipping.

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
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"Careful star-testing of the 10.1" Odyssey Compact I received last March and of the 10.1" my neighbor Doug Barnes picked up in mid-October suggests a high level of quality control which is astonishing. Diffraction patterns are virtually interchangeable, and both scopes show textbook optical results (both in-focus and out-of-focus)."
Lee Johnson, Coquitlam, B.C. Canada



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Richard Ziegler, Maumee, Ohio
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Mark Davenport, Pinellas Park, Fla.



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David Broad, Santa Barbara, Ca.



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FOR SALE—Equatorially fork mounted 29" f/4.5 scope, clock drive, sliding secondary cell, 4 1/2" finder with 20mm Erfle, 2" focuser and accessories, 55mm Plössl, 32mm Erfle, 2x Barlow, diagonal, Lumicon UHC, Telrad, adjustable weight system, electronic drive corrector, 6" polar shaft, 2" dec. shaft. Contact Ross Kennedy, Coleman Observatory, 10101 Forest Tower Way, Hackett, AR 72937.

FOR SALE—Meade #680 2" focuser, 1.25" and .965" eyepiece adapters, and JMI motofocus for the same: \$95 plus shipping. Contact David Blink (703) 461-9125.

FOR SALE—Celestron C8, upgraded with digital setting circles, Dec. motor, 12V drive corrector, hand controller, Losmandy rails, rings, tripod, wedge, diagonal, and 25mm eyepiece: \$1,195. Contact John Hoot (714) 498-5784 or (714) 498-5765.

FOR SALE—NGT 18" Newtonian telescope, like new. \$7,500. You pick up or meet at Texas Star Party. Contact Ed Greding, 3318 Casa Blanca, Corpus Christi, TX 78411. Phone (512) 853-6859 after 5 p.m.

ANNOUNCEMENT—The Ancient City Astronomy Club, Inc. meets every first Friday of the month at 8 p.m. in the First United Methodist Church at King and Riberia Street in St. Augustine, Florida. Write to ACAC, P.O. Box 546, St. Augustine, FL 32086-0546. Phone (904) 797-5704 or (904) 471-3054.

FOR SALE—Celestron dual-axis-quartz drive control system with hand control. Has declination motor reverse and jack for illuminator. Perfect condition. Used only a couple of times. \$175. Contact Mark Bro (515) 479-2877.

WANTED—Young woman wishes to correspond with young men and women interested in astronomy, wildlife, or nature. Contact Sarah Colman, P.O. Box 79001, Senderwood, 2145 South Africa.

WANTED—ASTRONOMY (1973, 1975, and 1976). Contact Robert Sonti (818)991-8575.

WANTED—Correspondence or information about gravity assist maneuvers. Any book titles and or groups associated with the same would also be most appreciated. Contact Tim Holmes, San Chuan Road, 98 Alley #47, Fengyuan, Taiwan.

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ANNOUNCEMENT — Chestmont Astronomical Society meets the third Sunday of each month at the Nature Center of Charlestown, Pennsylvania. Meetings begin at 7 p.m. We are seeking new members. Contact Dan Acker (215) 287-7979.

WANTED — Spacelight historian seeks NASA Gemini press kits for missions GT-7, GT-7/6A, GT-8, GT-9, and GT-9A and Gemini news reference book updates (from the Martin Co.) for missions GT-3, GT-8, GT-9A, GT-11, and GT-12. Will purchase originals or good photocopies or trade from extensive document collection. Contact David G. Fisher, 1138 Towncrest Road, Williamsport, PA 17701.

ANNOUNCEMENT — Interested in astronomy in North Central Ohio? Meetings are the first Saturday of each month at the Warren Rupp Observatory. Contact the Richland Astronomical Society, P.O. Box 1118, Mansfield, OH 44901-9998.

FOR SALE — Eclipse T-shirts. Contact June Cramer, 880 N. McClure, Lima, OH 45801.

FOR SALE — Set of six, 2" color filters: \$35. Lumicon Cassegrain E-Z Guider. \$150. 2" Deep-Sky filter: \$50. 1 1/4" Deep-Sky filter: \$30. RCA low-light Ultricon video camera: \$100. Contact William Vorce, 3512 Valley Forge, Las Vegas, NV 89110. Phone (702) 459-1367 or (702) 894-1509.

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WANTED — 1993 Exploring the Universe Calendar from ASTRONOMY magazine. Must be in excellent condition. Contact Michael De-Taglia, 425 Gail Drive, Wasilla, AK 99654.

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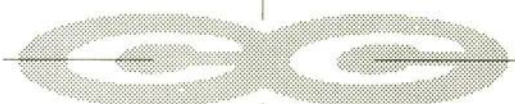
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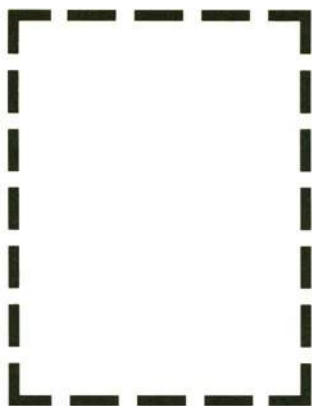


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Meetings & Events

June 25-July 2

Kopernik Astronomical Society Trip, Kitt Peak National Observatory, Lowell Observatory, Meteor Crater, and Grand Canyon. Sponsored by the Kopernik Astronomical Society. Write to Kopernik Observatory, 30 Front Street, Binghamton, NY 13905, or call Jay Sarton (607) 772-0660.

July 1-5

General Assembly of the Royal Astronomical Society of Canada, Halifax. Write to Halifax Centre of the RASC, 26 Randall Avenue, Apt. 4, Halifax, Nova Scotia, Canada B3M 1E2, or call David Lane (902) 420-5633.

July 1-August 31

PeGASus Project, British Columbia, Canada. Sponsored by the Prince George Astronomical Society. Contact: Ted Biech, 3330 22nd Avenue, CNC Box 021, Prince George, British Columbia, V2N 1P8 Canada. Phone (604) 562-2131.

July 10-15

UNIVERSE '93, San Diego State University. Sponsored by the Astronomical Society of the Pacific and *ASTRONOMY* magazine. Amateur astronomy product fair and talks July 10-11. Write to ASP, Meeting Information, 390 Ashton Avenue, San Francisco, CA 94112. Phone (415) 337-1100.

July 12-21

Space Week, Goodwood Library, Baton Rouge, Louisiana. Sponsored by the Baton Rouge Astronomical Society, Inc. Contact: Craig Brenden, 6348 Double Tree Court, Baton Rouge, LA 70817. Phone (504) 751-1685.

July 16-17

Astronomical League Northwest Regional Convention and High-Altitude Star Party, Table Mountain, near Ellensburg. Contact: Thom Jenkins, P.O. Box 8114, Spokane, WA 99203-0114. Phone (509) 838-1381.

July 16-17

Gateway to the Universe 1993, Munro Park, Ontario, Canada. Sponsored by the North Bay Astronomy Club. Contact: Merlin Clayton, North Bay Astronomy Club, 50 Van Horne Circle, North Bay, Ontario, Canada P1A 3L3.

July 16-18

7th Annual Rocky Mountain Star Stare, National Forest Service site, Colorado. Sponsored by the Colorado Springs Astronomical Society. Write to CSAS Star

Stare, P.O. Box 62022, Colorado Springs, CO 80962, or call Steve Bygren (719) 599-3612.

July 16-18

The Conjunction, Northfield Mountain Environmental Center. Contact: Jack Megas, 311 Surrey Road, Springfield, MA 01118.

July 16-18

Weekend Under the Stars, Fox Park, Wyoming. Write to Cheyenne Astronomical Society, 6614 North College #G, Cheyenne, WY 82009, or call Marty Curran (307) 635-5944.

July 17

Cluster Hunt Star Party, Crystal Falls Park, California. Write to Sonora Astronomical Society, 21581 Phoenix Lake Road #4, Sonora, CA 95370, or call Lance Kearns, (209) 536-0344 (before 8 p.m.).

July 17

Ohio Turnpike Astronomers' Associate Conference, Oberlin College, Oberlin, Ohio. Sponsored by the Cuyahoga Astronomical Association. Contact: Bill Gerling, P.O. Box 29089, Cleveland, OH 44129. Phone (216) 779-9779.

July 23-25

Highland Star Party, Cape Breton Highlands National Park. Write to Cape Breton Astronomical Society, 131 Green Acres Drive, Sydney River, Nova Scotia, Canada B1S 1K5, or call John Reppa (902) 562-2772.

July 23-25

Naturalist of the Night Weekend, Sleeping Giant Provincial Park, Thunder Bay. Write to Thunder Bay Centre of the RASC, 135 Hogarth Street, Thunder Bay, Ontario, Canada P7A 7H1, or call Bob Bishop (807) 767-5689.

July 29-31

ALCON '93, Sheraton Inn, Madison, Wisconsin (47th annual convention). Sponsored by the Madison Astronomical Society. Write to Madison Astronomical Society, ALCON '93, P.O. Box 14747, Madison, WI 53714-0747. □

Clubs, please submit meeting announcements at least four months before the date of the event. Readers, when you write to organizations listed in Meetings and Events, please include a self-addressed, legal-sized envelope with your request for information.

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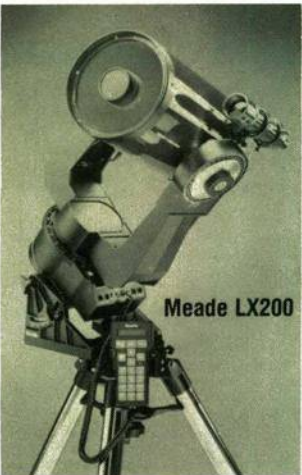
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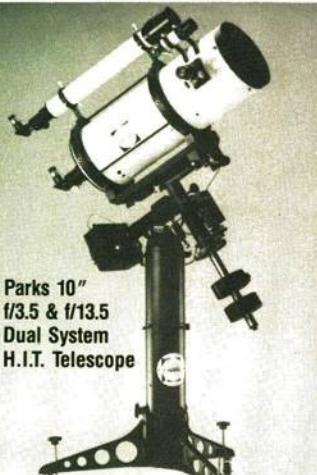
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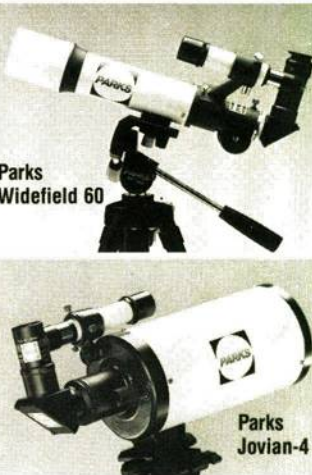
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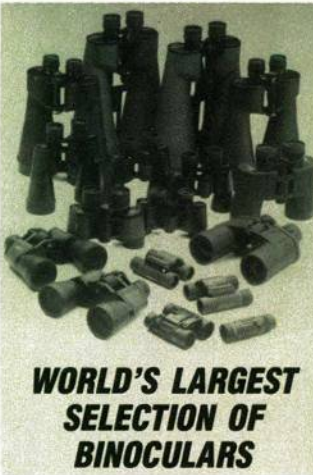
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Readings & Credits

Dance of the Double Sun (page 26)

"When Stars Coalesce," by Ken Croswell, *ASTRONOMY*, May 1985. Discusses how double stars can become one.

"Kinematic Clues to the Origin and Evolution of Low Mass Contact Binaries," by Edward F. Guinan and David H. Bradstreet, in *Formation and Evolution of Low Mass Stars*, edited by A. K. Dupree and M. T. V. T. Lago (Kluwer, 1988), pages 345-375. Gives evidence that contact binaries form from close binaries.

Neon Nova (page 36)

The Cambridge Atlas of Astronomy, edited by Jean Audouze and Guy Israel, (Cambridge University Press, 1988). A general description of novae and how they form.

Classical Novae, edited by M. F. Bode and A. Evans, (John Wiley and Sons, 1989). A technical reference book, but it includes finder charts and position and brightness information for many novae.

Getting Focused on Better Photos (page 58)

The Backyard Astronomer's Guide, by Terence Dickinson and Alan Dyer, (Camden House, revised 1993). A guide to the hobby and to selecting equipment.

Contains extensive chapters on astrophotography.

A Manual of Advanced Celestial Photography, by Brad D. Wallis and Robert W. Provin, (Cambridge University Press, 1988). Two experienced astrophotographers provide their advice on advanced astrophotography techniques.

Computing Mars and Jupiter (page 64)

Practical Astronomy with Your Calculator, by Peter Duffett-Smith (Cambridge University Press, 1988). Gives step-by-step routines for calculating planetary positions.

Explanatory Supplement to the Astronomical Almanac, edited by P. Kenneth Seidelmann, (University Science Books, 1992). The bible on how astronomers calculate all the entries in the Naval Observatory's annual *Astronomical Almanac*, including the positions and rotations of all the planets.

Mars (page 74)

Mars, by Peter Cattermole, (Chapman & Hall, 1992). A good survey of Mars written for the lay reader by a professional geologist.

Mars, edited by Hugh Kieffer, Bruce Jakosky, Conway Snyder, and Mildred Matthews, (University of Arizona Press, 1992). An enormous (1,400 pages), up-to-date summary of Mars knowledge.

Cover: illustration by Michael Carroll; **p. 4:** John Gleason, 11-inch f/10 Schmidt-Cassegrain, 60-minute exposure, Ektachrome 400 film; **p. 12:** Bill Chase; **p. 16:** Alan Dyer; **p. 18:** Jack Newton; **p. 19, left:** NAO; **right:** S. D. M. White, U. S. Briel, and J. P. Henry; **p. 20, top and bottom:** Jack Newton; **p. 22:** illustration by Michael Carroll; **p. 24:** illustration courtesy Thomas L. Hunt; **pp. 26-32:** illustrations by Michael Carroll; **pp. 34-35:** NASA/JPL; Peter Thomas, Cornell University; **p. 36:** illustration by Bob Eggleton; **p. 37:** photo by Patrick Wiggins and Bruce Grim; light curve courtesy of the American Association of Variable Star Observers; **p. 38:** courtesy of Karen Bjorkman, University of Wisconsin; **p. 39:** courtesy of Robert Hjellming, National Radio Astronomy Observatory; **pp. 40-44:** illustrations by Phil Kirchmeier; **p. 45:** courtesy of Avishai Dekel and Edmund Bertschinger; **p. 48:** William D. Gladson, Jr.; **p. 49:** G. C. Knight; **p. 53:** illustration by Phil Kirchmeier after M. Soma; **p. 58:** Darla Gawelski; **p. 59:** Chris Schur, 12.5-inch f/5 reflector, 60 minutes, hypered Tech Pan film focused with knife-edge focuser; **pp. 59-62:** illustrations by Steven G. Davis; **p. 61:** Chris Schur, 12.5-inch f/5 reflector, 60 minutes, hypered Tech Pan film focused with knife-edge focuser; **p. 63:** Chris Schur, 12.5-inch f/5 reflector, 60 minutes, hypered Tech Pan film focused with knife-edge focuser; **p. 64, top:** Donald C. Parker, August 27, 1988; **bottom:** Charles Capen, 16-inch Cassegrain; **pp. 68-73:** equipment photos by Darla Gawelski and Chris Becker; **p. 68:** illustrations by Thomas L. Hunt; **pp. 74-79:** Donald C. Parker, 16-inch reflector and Spectra Source Lynxx CCD camera (Mars photos) and Richard Berry (Mars globes); **p. 81, top:** Howard Banich, 50mm lens, Ektar 1000 film, 2-minute exposure; **bottom:** Matthew Boulton, 10-inch reflector at 320x on January 12, 1993; **p. 82, top left:** Jack Newton, 25-inch reflector, SBIG ST-6 CCD camera; **bottom left:** Patrick Martinez and Pierre-Michel Berge, 500mm camera, Spectra Source Lynxx CCD camera, processing by Cyril Cavadore; **bottom right:** Don Bruns, 8-inch SCT, Ektar 25 film, 10-second exposure on March 4, 1993; **pp. 83, top:** Ed Vega, 24mm lens, Kodachrome 400 film; **bottom left:** Jack Newton, 25-inch reflector, SBIG ST-6 CCD camera; **bottom right:** Sang Ho Cho, 4-inch f/5 refractor, Fuji Super HG 400 film, 30-minute exposure on February 9, 1993; **p. 84:** Ronald W. Kohl, 20-inch Cassegrain, Photometrics Star I CCD camera, 3-minute exposure; **p. 102:** NASA.

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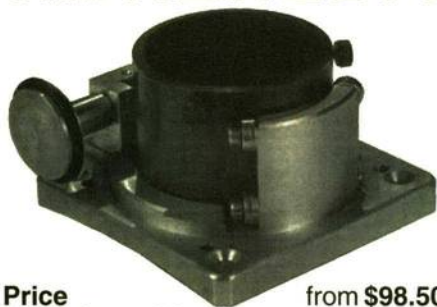
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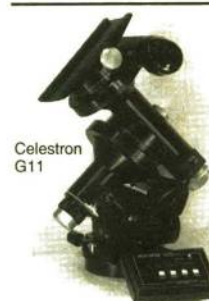
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For literature and a complete description of the GP-C8 telescope, contact your local Celestron dealer or contact Celestron.

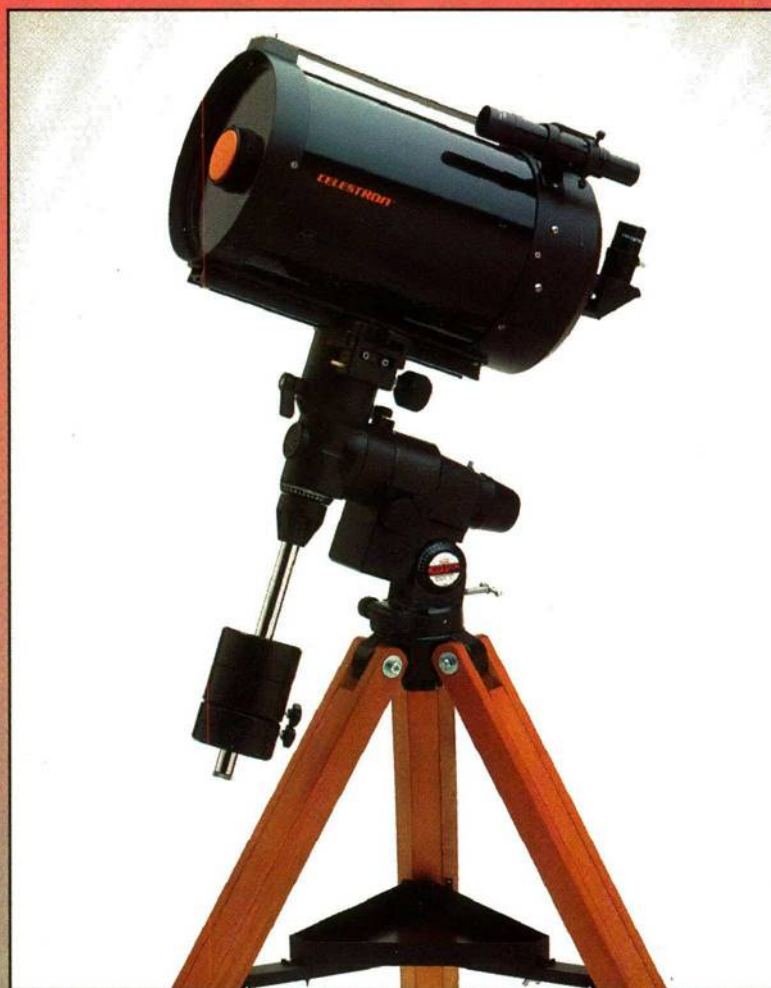


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